CHAPTER 1

BOILERS

Learning Objectives: Describe the principles and theory of steam generation. Identify different types of boilers and the design requirements for boilers. Describe the purpose and operation of the different types of boilers and their fittings and accessories. Describe the methods and procedures for the testing and treatment of boiler water. Describe methods and procedures involved in fireside and waterside cleaning.

A boiler is an enclosed vessel in which water is heated and circulated, either as hot water or steam, to produce a source for either heat or power. A central heating plant may have one or more boilers that use gas, oil, or coal as fuel. The steam generated is used to heat buildings, provide hot water, and provide steam for cleaning, sterilizing, cooking, and laundering operations. Small package boilers also provide steam and hot water for small buildings.

A careful study of this chapter can help you acquire useful knowledge of steam generation, types of boilers pertinent to Seabee operations, various fittings commonly found on boilers, and so on. The primary objective of this chapter is to lay the foundation for you to develop skill in the operation, maintenance, and repair of boilers.

STEAM GENERATION THEORY

Learning Objective: Describe the principles and theory of steam generation.

To acquaint you with some of the fundamentals underlying the process of steam operation, suppose that you set an open pan of water on the stove and turn on the heat. You find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the BOILING POINT (212°F or 100°C at sea level). a physical change occurs in the water; the water starts vaporizing. When you hold the temperature at the boiling point long enough, the water continues to vaporize until the pan is dry. A point to remember is that THE TEMPERATURE OF WATER DOES NOT INCREASE BEYOND THE BOILING POINT. Even if you add more heat after the water starts to boil, the water cannot get any hotter as long as it remains at the same pressure.

Now suppose you place a tightly fitting lid on the pan of boiling water. The lid prevents the steam from escaping from the pan and this results in a buildup of pressure inside the container. However, when you make an opening in the lid, the steam escapes at the same rate it is generated. As long as water remains in the pan and as long as the pressure remains constant, the temperature of the water and steam remains constant and equal.

The steam boiler operates on the same basic principle as a closed container of boiling water. By way of comparison, it is as true with the boiler as with the closed container that steam formed during boiling tends to push against the water and sides of the vessel. Because of this downward pressure on the surface of the water, a temperature in excess of 212°F is required for boiling. The higher temperature is obtained simply by increasing the supply of heat; therefore, the rules you should remember are as follows:

1. All of the water in a vessel, when held at the boiling point long enough, will change into steam. AS LONG AS THE PRESSURE IS HELD CONSTANT, THE TEMPERATURE OF THE STEAM AND BOILING WATER REMAINS THE SAME.

2. AN INCREASE IN PRESSURE RESULTS IN AN INCREASE IN THE BOILING POINT TEMPERATURE OF WATER.

A handy formula with a couple of fixed factors will prove this theory. The square root of steam pressure multiplied by 14 plus 198 will give you the steam temperature. When you have 1 psig of steam pressure, the square root is one times 14 plus 198 which equals 212°F which is the temperature that the water will boil at 1 psig.

There are a number of technical terms used in connection with steam generation. Some of these commonly used terms you should know are as follows:

- "Degree" is defined as a measure of heat intensity.
- "Temperature" is defined as a measure in degrees of sensible heat. The term *sensible heat* refers to heat that can be measured with a thermometer.
- "HEAT" is a form of energy measured in British thermal units (Btu). One Btu is the amount of heat required to raise 1 pound of water 1 degree Fahrenheit at sea level.
- "Steam" means water in a vapor state. DRY SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and it contains no water in suspension. WET SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and it contains water particles in suspension.
- The "QUALITY" of steam is expressed in terms of percent. For instance, if a quantity of wet steam consists of 90 percent steam and 10 percent moisture, the quality of the mixture is 90 percent.
- "SUPERHEATED STEAM" is steam at a temperature higher than the saturation temperature corresponding to pressure. For example, a boiler may operate at 415 psig (pounds per square inch gauge). The corresponding saturation temperature for this pressure is 483°F, and this will be the temperature of the water in the boiler and the steam in the drum. (Charts and graphs are available for computing this pressure-temperature relationship.) This steam can be passed through a superheater where the pressure remains about the same, but the temperature will be increased to some higher figure.

Q1. When heat is applied to water, what physical change occurs?

Q2. How is a "degree" of heat defined?

Q3. As long as the pressure in a boiler is held constant, what factor remains the same in the boiler?

BOILER DESIGN REQUIREMENTS

Learning Objective: Describe the design requirements for boilers.

A boiler must meet certain requirements before it is considered satisfactory for operation. Three important requirements for a boiler are as follows:

1. The boiler must be safe to operate.
2. The boiler must be able to generate steam at the desired rate and pressure.
3. The boiler must be economical to operate.

NOTE

Make it a point to familiarize yourself with the boiler code and other requirements applicable to the area in which you are located.

Design rules for boilers are established by the ASME (American Society of Mechanical Engineers). These rules are general guidelines used by engineers when designing boilers. These rules require that for economy of operation and to generate steam at the desired rate and pressure, a boiler must have the following attributes:

- Adequate water and steam capacity
- Rapid and positive water circulation
- A large steam generating surface
- Heating surfaces that are easy to clean on both water and gas sides
- Parts accessible for inspection
- A correct amount and proper arrangement of heating surface
- A firebox for efficient combustion of fuel

Q4. What three requirements must a boiler meet before being considered satisfactory for operation?

Q5. What organization has established guidelines for designing boilers?

TYPES OF BOILERS

Learning Objective: Identify the different types of boilers and describe the operation of each.

The Utilitiesman is concerned primarily with the FIRE-TUBE type of boiler, since it is the type generally used in Seabee operations. However, the WATER-TUBE type of boiler may occasionally be used at some activities. The information in this chapter primarily concerns the different designs and construction feature: of fire-tube boilers.

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The basis for identifying the two types is as follows:

- WATER-TUBE BOILERS are those in which the products ofcombustion surround the tubes through which the water flows.
- FIRE-TUBE BOILERS are those in which the products of combustion pass through the tubes and the water surrounds them.

WATER-TUBE BOILERS

Water-tube boilers may be classified in a number of ways. For our purpose, they are classified as either straight tube or bent tube. These classes are discussed separately in succeeding sections. To avoid confusion, make sure you study carefully each illustration referred to throughout the discussion.

Straight Tube

The STRAIGHT-TUBE class of water-tube boilers includes three types:

1. Sectional-header cross drum
2. Box-header cross drum
3. Box-header longitudinal drum

In the SECTIONAL-HEADER CROSS DRUM boiler with vertical headers, the headers are steel boxes into which the tubes are rolled. Feedwater enters and passes down through the downcomers (pipes) into the rear sectional headers from which the tubes are supplied. The water is heated and some of it changes into steam as it flows through the tubes to the front headers. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle that helps to separate the water and steam.

Steam is removed from the top of the drum through the dry pipe. This pipe extends along the length of the drum and has holes or slots in the top half for steam to enter.

Headers, the distinguishing feature of this boiler. are usually made of forged steel and are connected to the drums with tubes. Headers may be vertical or at right angles to the tubes. The tubes are rolled and flared into the header. A handhold is located opposite the ends of each tube to facilitate inspection and cleaning. Its purpose is to collect sediment that is removed by blowing down the boiler.

Baffles are usually arranged so gases are directed across the tubes three times before being discharged from the boiler below the drum.

BOX-HEADER CROSS DRUM boilers are shallow boxes made of two plates—a tube-sheet plate that is bent to form the sides of the box, and a plate containing the handholds that is riveted to the tube-sheet plate. Some are designed so that the front plate can be removed for access to tubes. Tubes enter at right angles to the box header and are expanded and flared in the same manner as the sectional-header boiler. The boiler is usually built with the drum in front. It is supported by lugs fastened to the box headers. This boiler has either cross or longitudinal baffling arranged to divide the boiler into three passes. Water enters the bottom of the drum, flows through connecting tubes to the box header, through the tubes to the rear box header, and back to the drum.

BOX-HEADER LONGITUDINAL DRUM boilers have either a horizontal or inclined drum. Box headers are fastened directly to the drum when the drum is inclined. When the drum is horizontal, the front box header is connected to it at an angle greater than 90 degrees. The rear box header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type.

Bent Tube

Bent tube boilers usually have three drums. The drums are usually of the same diameter and positioned at different levels with each other. The uppermost or highest positioned drum is referred to as the STEAM DRUM, while the middle drum is referred to as the WATER DRUM, and the lowest, the MUD DRUM. Tube banks connect the drums. The tubes are bent at the ends to enter the drums radially.

Water enters the top rear drum, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum. The steam returns to the top rear drum through the upper row of tubes, while the water travels through the tubes in the lower rear drum by tubes extending across the drum and enters a small collecting header above the front drum.

Many types of baffle arrangements are used with bent-tube boilers. Usually, they are installed so that the inclined tubes between the lower drum and the top front drum absorb 70 to 80 percent of the heat. The water-tube boilers discussed above offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity ranging from 100.000 to 1,000,000 pounds of steam per hour. In case of tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, it can also be modified for tiring by oil or coal. Still another advantage is that it is easy to get into sections inside the furnace to clean and repair them. There are also several disadvantages common to water-tube boilers. One of the main drawbacks of water-tube boilers is their high construction cost. The large assortment of tubes required of this boiler and the excessive weight per unit weight of steam generated are other unfavorable factors.

FIRE-TUBE BOILERS

There are four types of fire-tube boilers—the Scotch marine boiler. the vertical-tube boiler, the horizontal return tubular boiler. and the firebox boiler. These four types of boilers are discussed in this section.

Scotch Marine Boiler

The Scotch marine tire-tube boiler is especially suited to Seabee needs. Figure 1-1 is a portable Scotch marine tire-tube boiler. The portable unit can be moved easily and requires only a minimal amount of foundation work. As a complete self-contained unit. its design includes automatic controls. a steel boiler. and burner equipment. These features are a big advantage because no disassembly is required when you must move the boiler into the field for an emergency.

The Scotch marine boiler has a two-pass (or more) arrangement of tubes that run horizontally to allow the heat inside the tubes to travel back and forth. It also has an internally fired furnace with a cylindrical combustion chamber. Oil is the primary fuel used to fire the boiler; however. it can also be fired with wood, coal, or gas. A major advantage of the Scotch marine boiler is that it requires less space than a water-tube boiler and can be placed in a room that has a low ceiling.

The Scotch marine boiler also has disadvantages. The shell of the boiler runs from 6 to 8 feet in diameter, a detail of construction that makes a large amount of reinforcing necessary. The fixed dimensions of the internal surface cause some difficulty in cleaning the sections below the combustion chamber. Another drawback is the limited capacity and pressure of the Scotch marine boiler.

An important safety device sometimes used is the fusible plug that provides added protection against low-water conditions. In case of a low-water condition. the fusible plug core melts, allowing steam to escape, and a loud noise is emitted which provides a warning to the operator. On the Scotch boiler the plug is located in the crown sheet, but sometimes it is placed in the upper back of the combustion chamber. Fusible plugs are discussed in more detail later in this chapter.

Access for cleaning, inspection, and repair of the boiler watersides is provided through a manhole in the top of the boiler shell and a handhold in the water leg. The manhole opening is large enough for a man to enter the

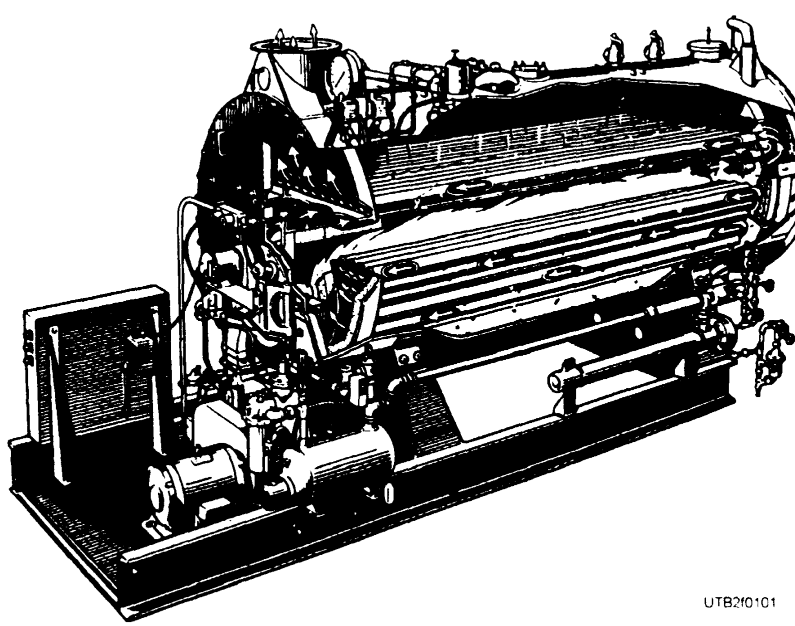
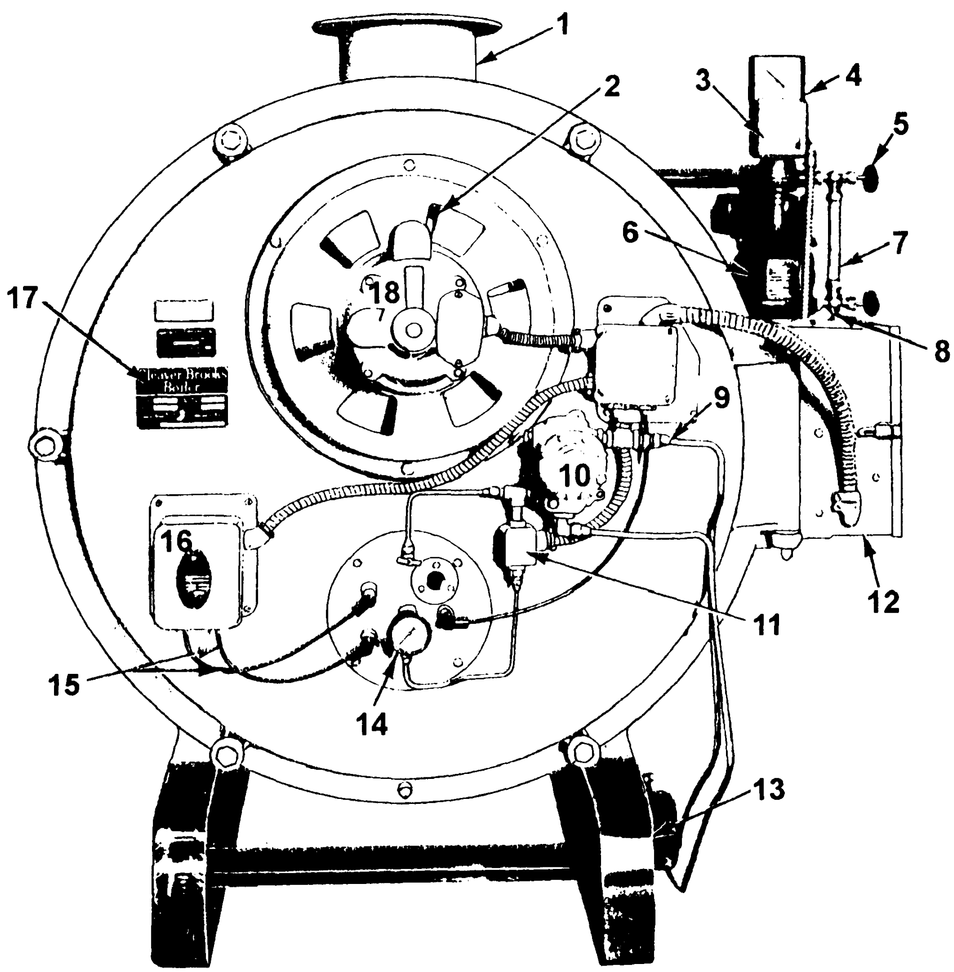


Figure 1-1.—Scotch marine type of fire-tube boiler.

boiler shell for inspection, cleaning, and repairs. On such occasions, always ensure that all valves are secured, locked, tagged, and that the person in charge knows you are going to enter the boiler. Additionally, always have a person located outside of the boiler standing by to aid you in case of an incident occurring that would require you to need assistance. The handholds are openings large enough to permit hand entry for cleaning, inspection, and repairs to tubes and headers. Figure 1-2 shows a horizontal fire-tube boiler used in low-pressure applications. Personnel in the Utilitiesman rating are assigned to operate and maintain this type of boiler more often than any other type of boiler.

Vertical-Tube Boiler

In some fire-tube boilers, the tubes run vertically, as opposed to the horizontal arrangement in the Scotch boiler. The VERTICAL-TUBE boiler sits in an upright position, as shown in figure 1-3. Therefore, the products of combustion (gases) make a single pass, traveling straight up through the tubes and out the stack. The vertical fire-tube boiler is similar to the horizontal fire-tube boiler in that it is a portable, self-contained unit requiring a minimum of floor space. Handholds are also provided for cleaning and repairing. Though self-supporting in its setting (no brickwork or foundation being necessary), it MUST be level. The vertical



1. VENTS
2. AIR DAMPER
3. HIGH-LIMIT PRESSURE CONTROL
4. STEAM PRESSURE GAUGE
5. GAUGE GLASS SHUTOFF COCK
6. LOW-WATER CONTROL
7. WATER LEVEL GAUGE
8. BURNER SWITCH
9. PRIMING TEE
10. OIL UNIT, TWO STAGE
11. SOLENOID OIL VALVE (Maintenance)
12. SERVICE CONNECTION BOX
13. FUEL OIL SUPPLY CONNECTION
14. FUEL OIL PRESSURE GAUGE
15. IGNITION CABLE
16. IGNITION CABLE
17. NAMEPLATE
18. BLOWER MOTOR

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Figure 1-2.—Horizontal fire-tube boiler used in low-pressure applications.

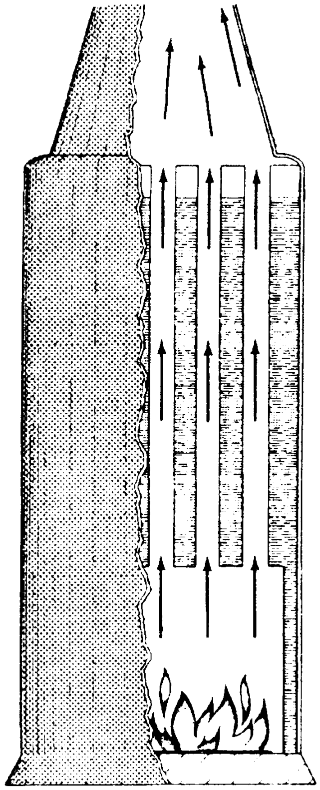


Figure 1-3.—Cutaway view of a vertical fire-tube boiler.

fire-tube boiler has the same disadvantages as that of the horizontal-tube design—limited capacity and furnace volume.

Before selecting a vertical fire-tube boiler, you must know how much overhead space is in the building where it will be used. Since this boiler sits in an upright position, a room with a high ceiling is necessary for its installation.

The blowdown pipe of the vertical tire-tube boiler is attached to the lowest part of the water leg. and the feedwater inlet opens through the top of the shell. The boiler fusible plug is installed either (1) in the bottom tube sheet or crown sheet or (2) on the outside row of tubes, one third of the height of the tube from the bottom.

Horizontal Return Tubular Boiler

In addition to operating portable boilers, such as the Scotch marine and vertical fire-tube boilers. the Utilitiesman must also be able to operate stationary boilers, both in the plant and in the field. A STATIONARY BOILER can be defined as one having a permanent foundation and not easily moved or relocated. A popular type of stationary fire-tube boiler is the HORIZONTAL RETURN TUBULAR (HRT) boiler shown in figure 1-4.

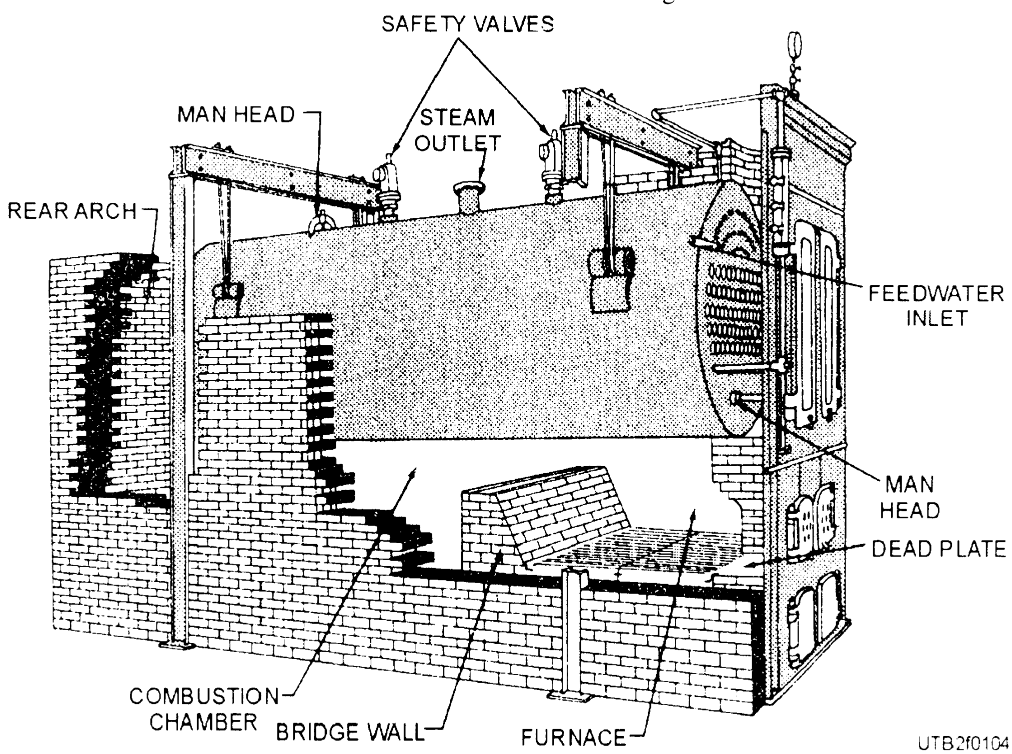


Figure 1-4.—Horizontal return tubular (HRT) fire-tube boiler.

The initial cost of the HRT boiler is relatively low and installing it is not too difficult. The boiler setting can be readily changed to meet different fuel requirements—coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

The gas flows in the HRT boiler from the firebox to the rear of the boiler. It then returns through the tubes to the front where it is discharged to the breaching and out the stack.

The HRT boiler has a pitch of 1 to 2 inches to the rear to allow sediment to settle toward the rear near the bottom blowdown connection. The fusible plug is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhole in the upperpart of the shell. Those over 48 inches in diameter must have a manhole in the lower, as well as in the upper, part of the shell. Do not fail to familiarize yourself with the location of these and other essential parts of the HRT boiler. The knowledge you acquire will definitely help in the performance of your duties with boilers.

Firebox Boiler

Another type of fire-tube boiler is the FIREBOX boiler that is usually used for stationary purposes. A split section of a small firebox boiler is shown in figure 1-5. Gases in the firebox boiler make two passes through the tubes. Firebox boilers require no setting except possibly an ash pit for coal fuel. As a result, they can be quickly installed and placed in service. Gases travel from the firebox through a group of tubes to a reversing chamber. They return through a second set of tubes to the flue connection on the front of the boiler and are then discharged up the stack.

Q6. What are the two types of boilers?

Q7. What are the four types office-tube boilers?

Q8. What is the primary factor that allows the firebox boiler to be quickly installed and placed into service?

BOILER FITTINGS AND ACCESSORIES

Learning Objective: Describe the function and operation of the different types of boiler fittings and accessories.

Now that the basic structure of a boiler has been explained, boiler fittings (fig. 1-6) and the operation or function of various devices, such as controls, valves, and try cocks, must be presented. A sufficient number of essential boiler fittings and accessories are discussed in this section to provide a background for further study. As a reminder, and in case you should run across some unit

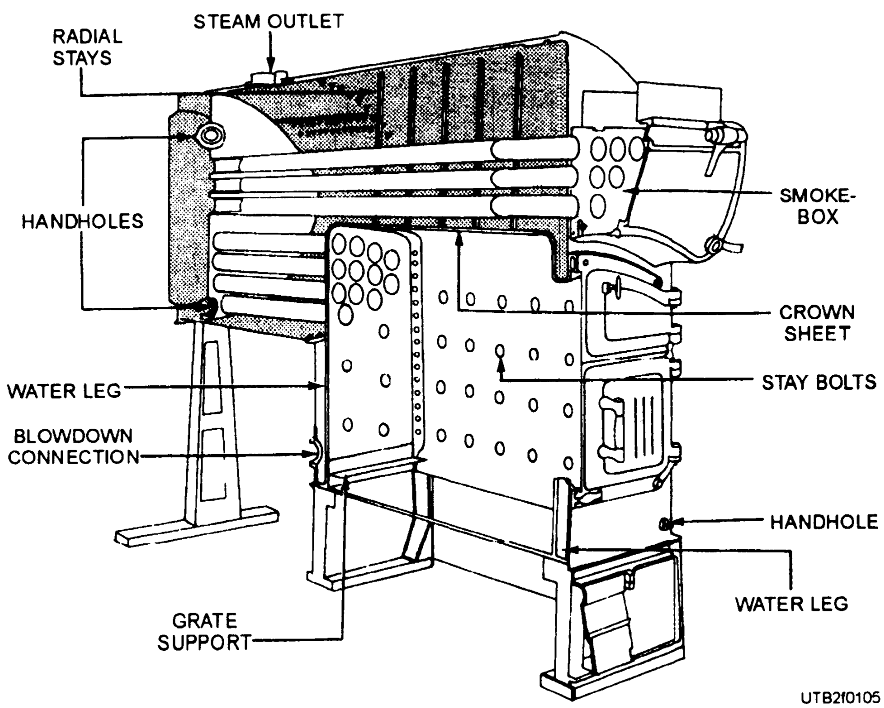


Figure 1-5.—Split section of a small firebox boiler.

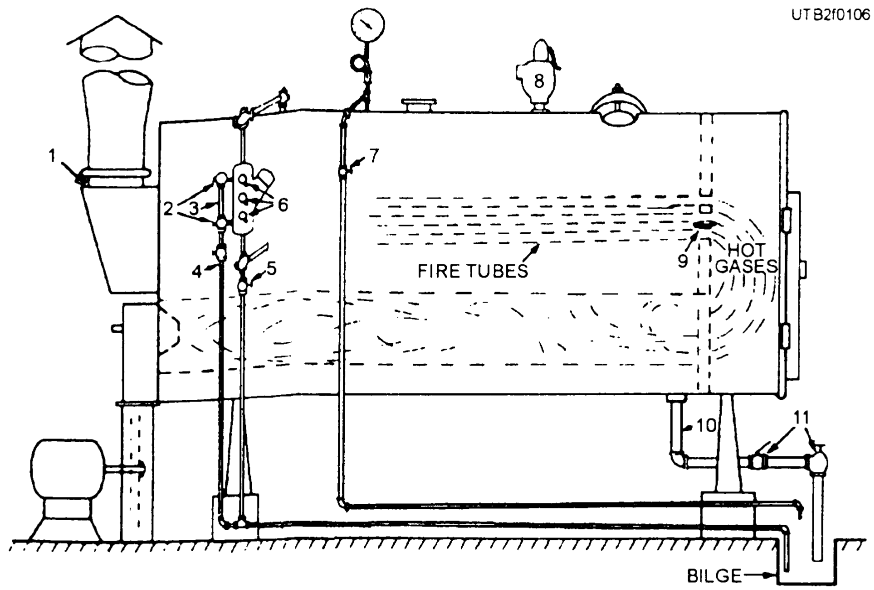


Figure 1-6.—Boiler fittings.

or device not covered in this text, check the manufacturer's manual for information on details of its construction and method of operation.

The term *fittings* include various control devices on the boiler. Fittings are vitally important to the economy of operation and safety of personnel and equipment. You must understand fittings if you are to acquire skill in the installation, operation, and servicing of steam boilers.

All boilers require boiler fittings to operate safely. The American Society of Mechanical Engineers (ASME) requires all boiler fittings to be made of materials that withstand the pressure and temperatures that boilers are subject to. All of the boiler fittings discussed are important and must be operated and maintained properly to operate a boiler safely.

AIR COCK

An air cock is located in the uppermost steam space of a boiler, as shown in item 7 in figure 1-6. This design allows for air to enter and escape during filling and draining of the boiler. Before firing a cold boiler with no steam pressure, the air cock is opened to allow air to escape during the heating of the water. When steam begins to come out of the air cock piping, close the valve.

CHIMNEYS, DRAFT FANS, AND BREECHINGS

Chimneys are necessary for discharging the products of combustion at an elevation high enough to comply with health requirements and to prevent a nuisance because of low-flying smoke, soot, and ash. A boiler needs a draft to mix air correctly with the fuel supply and to conduct the flue gases through the complete setting. The air necessary for combustion of fuel cannot be supplied normally by a natural draft. Therefore, draft fans may be used to ensure that the air requirements are properly attained. Two types of draft fans used on boilers are forced-draft and induced-draft fans. They are damper controlled and usually are driven by an electric motor.

The FORCED-DRAFT fan forces air through the fuel bed, or fuel oil burner, and into the furnace to supply air for combustion. The INDUCED-DRAFT fan draws gases through the setting, thus facilitating their removal through the stack. Breechings (see item 1 in fig. 1-6) are used to connect the boiler to the stack. They are usually made of sheet steel with provision for expansion and contraction. The breaching may be carried over the boilers, in back of the setting, or even under the boiler room floor. Keep breechings as short as possible and free from sharp bends and abrupt changes in area. The cross-sectional area should be approximately 20 percent greater than that of the stack to keep draft loss to a minimum. A breaching with a circular cross section causes less draft loss than one with a rectangular or square cross section.

BLOWDOWN VALVES

Blowdown valves on boilers are located on the water column and on the lowest point of the water spaces of the boiler (see items 2, 5, 10, and 11 in fig. 1-6). The blowdown valves on a boiler installed at the bottom of each water drum and header are used to remove scale and other foreign matter that have settled in the lowest part of the water spaces. Boilers are also blown down to control concentration ofdissolved and suspended solids in boiler water. The water column blowdown permits removal of scale and sediments from the water column. Additionally, some boilers have what is called a surface blowdown. The surface blowdown is located at the approximate water level so as to discharge partial steam and water. The surface blowdown removes foaming on the top of the water surface and any impurities that are on the surface of the water.

FUSIBLE PLUGS

FUSIBLE PLUGS are used on some boilers to provide added protection against low water. They are constructed of bronze or brass with a tapered hole drilled lengthwise through the plug. They have an even taper from end to end. This tapered hole is filled with a low-melting alloy. consisting mostly of tin. There are two types of fusible plugs—fire actuated and steam actuated.

The FIRE-ACTUATED plug is filled with an alloy of tin, copper. and lead with a melting point of 445°F to 450°F. It is screwed into the shell at the lowest permissible water level. One side of the plug is in contact with the tire or hot gases, and the other side is in contact with the water (see item 9). As long as the plug is covered with water, the tin does not melt. When the water level drops below the plug, the tin melts and blows out. Once the core is blown out, a whistling noise will warn the operator. The boiler then must be taken out of service to replace the plug.

The STEAM-ACTUATED plug is installed on the end of a pipe outside the drum. The other end of the pipe. which is open, is at the lowest permissible water level in the steam drum. A valve is usually installed between the plug and the drum. The metal in the plug melts at a temperature below that of the steam in the boiler. The pipe is small enough to prevent water from circulating in it. The water around the plug is much cooler than the water in the boiler as long as the end of the pipe is below the water level. However, when the water level drops below the open end of the pipe, the cool water runs out of the pipe and steam heats the plug. The hot steam melts and blows the tin out, allowing steam to escape from the boiler warning the operator. This type of plug can be replaced by closing the valve in the piping. It is not necessary to take the boiler out of service to replace the plug.

Fusible plugs should be renewed regularly once a year. Do NOT refill old casings with new tin alloy and use again. ALWAYS USE A NEW PLUG.

WATER COLUMN

A WATER COLUMN (fig. 1-7) is a hollow vessel having two connections to the boiler. Water columns come in many more designs than the two shown in figure 1-7; however, they all operate to accomplish the same principle. The top connection enters the steam drum of the boiler through the top of the shell or drum. The water connection enters the shell or head at least 6 inches below the lowest permissible water level. The purpose of the water column is to steady the water level in the gauge glass through the reservoir capacity of the column. Also, the column may eliminate the obstruction on small diameter, gauge-glass connections by serving as a sediment chamber.

The water columns shown are equipped with high- and low-water alarms that sound a whistle to warn the operator. The whistle is operated by either of the two floats or the solid weights shown in figure 1-7.

Water Level Control

The water level control not only automatically operates the boiler feed pump but also safeguards the boiler against low water by stopping the burner. Various types of water level controls are used on boilers. At Seabee activities, boilers frequently are equipped with a float-operated type, a combination float and mercury switch type, or an electrode probe type ofautomatic water level control. Each of these types is described below.

The FLOAT-OPERATED TYPE of feedwater control, similar in design to the feedwater control shown in figure 1-8, is attached to the water column. This control uses a float, an arm, and a set of electrical contacts. As a low-water cutoff, the float rises or lowers with the water level in an enclosed chamber. The chamber is connected to the boiler by two lines, which allow the water and steam to have the same level in the float chamber as in the boiler. An arm and linkage connects the float to a set of electrical contacts that operate the feedwater pump when the water lowers the float. When the water supply fails or the pump becomes inoperative and allows the water level to continue to drop, another set of contacts operates an alarm bell, buzzer, or whistle, and secures the burners.

The COMBINATION FLOAT AND MERCURY SW ITCH TYPE of water level control shown in figure 1-8

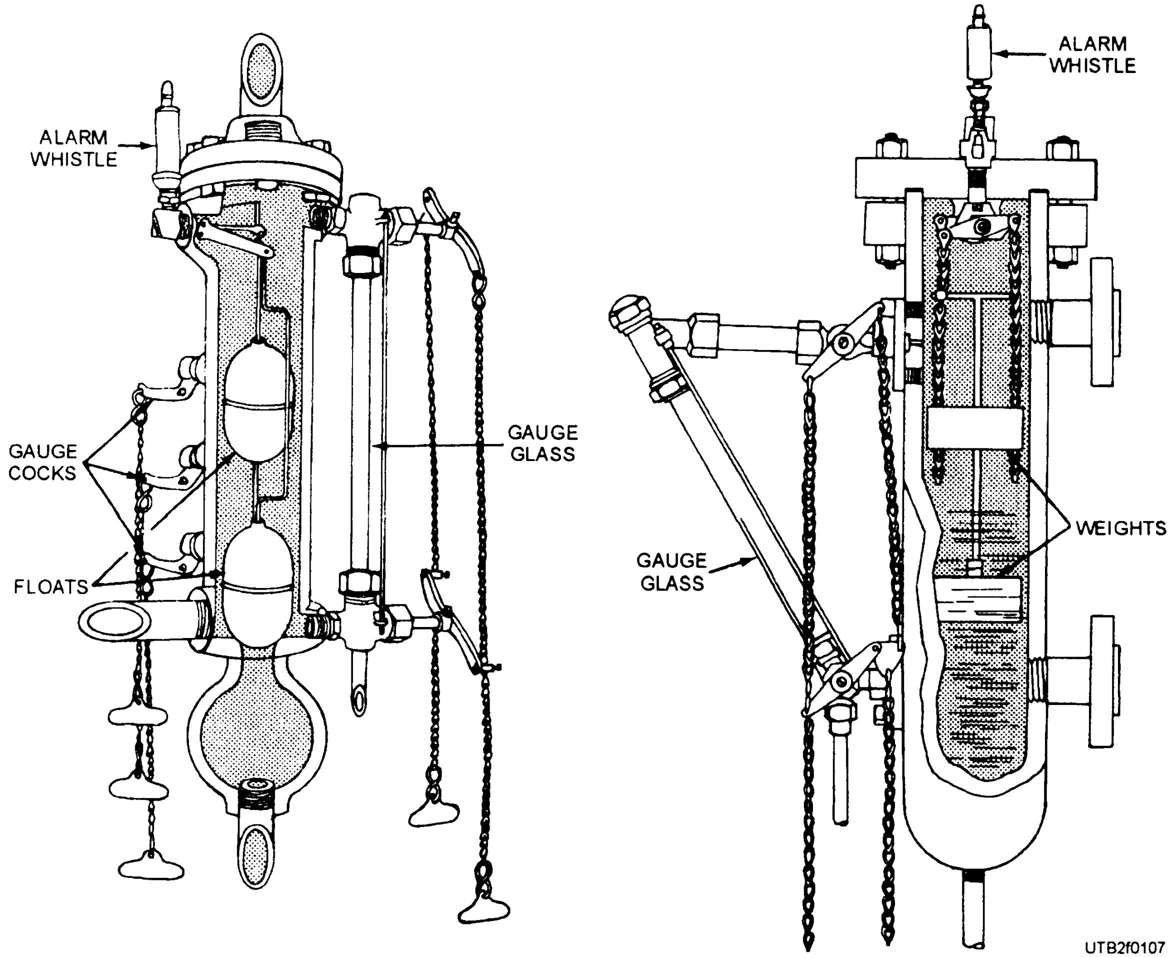


Figure 1-7.—Typical water columns.

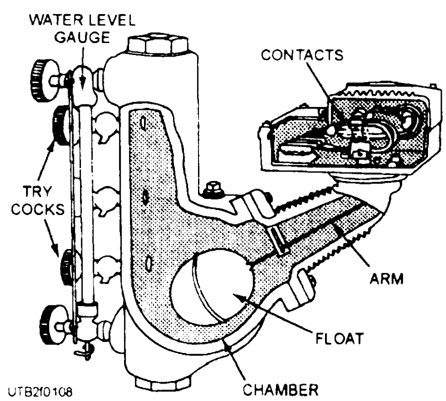


Figure 1-8.—Combination float and mercury switch type of feedwater control.

reacts to changes made within a maintained water level by breaking or making a complete control circuit to the feedwater pump. It is a simple two-position type control, having no modulation or differential adjustment or setting. As all water level controllers should be, it is wired independently from the programmer. The control is mounted at steaming water level and consists of a pressurized float, a pivoted rocker arm, and a cradle-attached mercury switch. The combination float and mercury switch type of water level control functions as follows: As the water level within the boiler tends to drop, the float lowers. As the float lowers, the position of the mercury switch changes. Once the float drops to a predetermined point, the mercury within the tube runs to its opposite end. This end contains two wire leads, and when the mercury covers both contacts, a circuit is completed to energize the feedwater pump. The pump, being energized, admits water to the boiler. As the water level within the boiler rises, the float rises. As the float rises, the position of the mercury switch changes. Once the float rises to a predetermined point, the mercury runs to the opposite end of its tube, breaking the circuit between the wire leads and securing the feedwater pump. The feedwater pump remains off until the water level again drops low enough to trip the mercury switch.

The ELECTRODE PROBE TYPE of feedwater control (fig. 1-9) and low-water cutoff consists of an electrode assembly and a water level relay. The electrode assembly contains three electrodes of different lengths correspondin g to high. low, and burner cutout in the boiler drum.

To understand the operation of a boiler circuit, refer to figures 1-9 and 1-10 as you read the information in table 1-1. Although this information is not complete. it is presented here to acquaint you with the operation of the electrode type of boiler water level control.

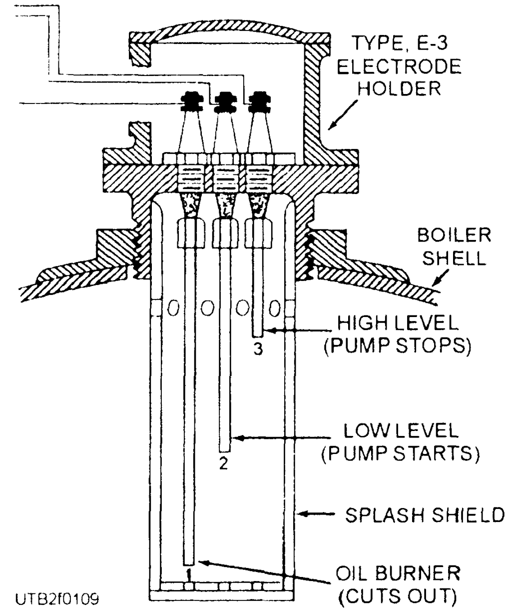


Figure 1-9.—Electrode type of water level control.

Try Cocks

The location of the try cocks is shown as item 6 in figure 1-6. The purpose of the try cocks is to prove the water level in the boiler. You may see water in the gauge glass. but that does not mean that the water level is at that position in the boiler. lf the gauge glass is clogged up. the water could stay in the glass giving a false reading. The try cocks, on the other hand, will blow water. steam. or a mixture of steam and water out of them when they are manually opened. When steam is discharged from the lowest try cock, you have a low-water condition.

Table 1-1.—Operation of a Boiler Circuit

Operation	Action	Results
When the feed pump switch is in the auto position.	The feed pump motor is energized.	The feed pump will operate under control of the water level relay (item #6 in fig. 1-10).
When the water level in the boiler reaches the level of electrode #3.	The circuit through the electrode is grounded and this completes the circuit.	All of the CONTACTS labeled #6 change position. The three feed pump contacts that are normally closed, i.e., 6-1, 6-2, and 6-3 open, and contact 6-4 closes which maintains the grounded circuit through electrode #2.
When the water level falls below electrode #2.	The circuit through relay #6 will no longer be grounded because the water is not in contact with the electrode.	This de-energizes relay #6, so all of the CONTACTS labeled #6 return to their normal positions. Contacts 6-1 through 6-3 close and 6-4 opens. The feedwater pump is energized and water is pumped into the boiler.
When the water level rises again to electrode #3.	Relay #6 will energize again.	The cycle continues and the water level in the boiler is maintained.
When the water level falls below electrode #1.	Relay #5 will be de-energized.	CONTACT 5-1 will open. This action de-energizes the entire control circuit. The boiler is now shut down and the low-water alarm is sounded.

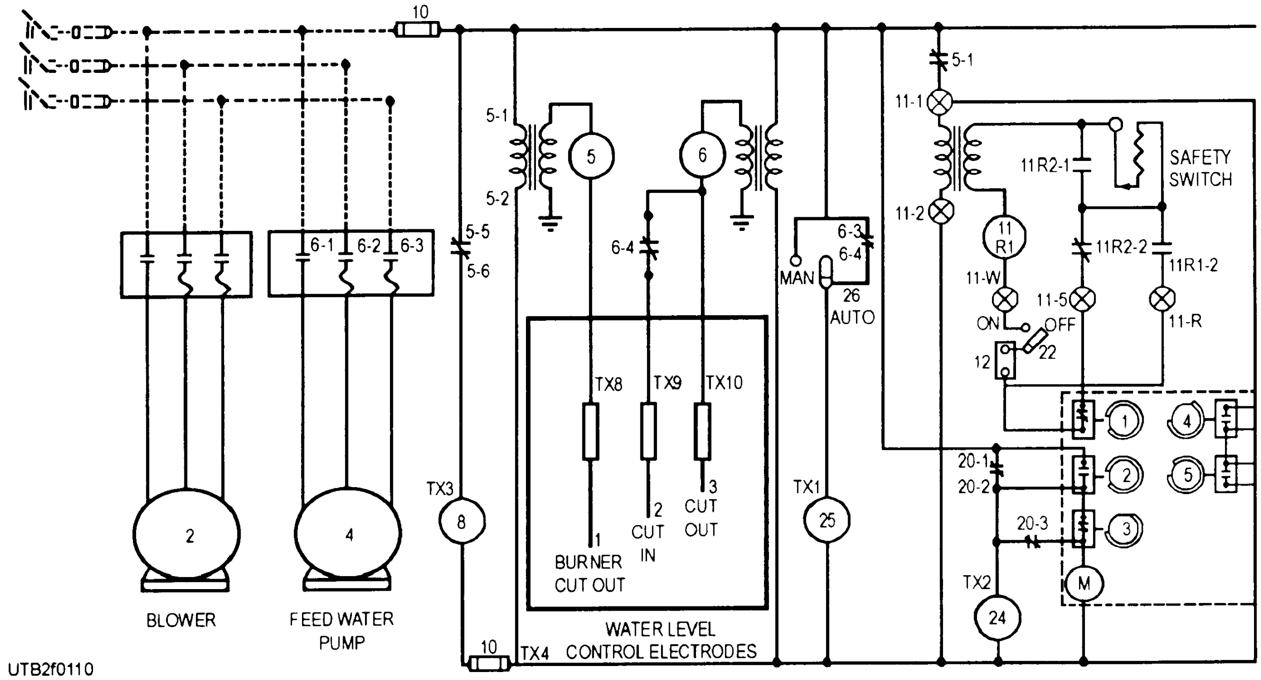


Figure 1-10.—A typical boiler circuit.

WARNING

When the water level is proved using the try cocks, personnel should stand off to the side of the try cocks away from the discharge. The discharged hot steam or very hot water can cause severe burns.

Gauge Glass

The gauge glass is located on the water column, as shown in figure 1-6, item 3. The gauge glass allows the boiler operator to see the water level in the boiler. Normally there are two valves associated with the gauge glass. One valve is located at the top and one is located at the bottom of the gauge glass. These two valves, named gauge cock valves (fig. 1-6, item 2). secure the boiler water and steam from the gauge glass. Another valve (fig. 1-6, item 4) located in line with the gauge glass, is used to blow the gauge glass down.

SAFETY VALVE

The SAFETY VALVE shown in figure 1-11 is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler from increasing beyond the safe operating limit. The safety valve is installed in a vertical position and attached directly to the steam space of the boiler. The location can be seen in figure 1-6, item 8. Each boiler has at least one safety valve; when the boiler has more than 500 square feet of heating surface, two or more valves are required.

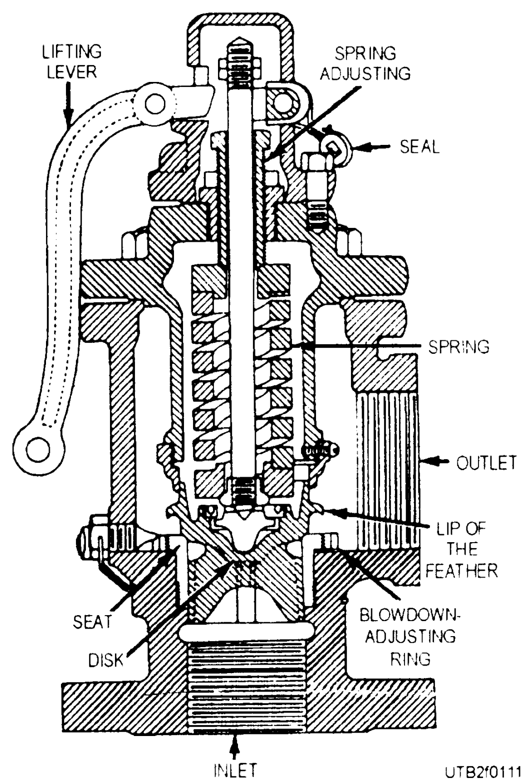


Figure 1-11.—A spring-loaded safety valve.

There are several different types of safety valves in use but all are designed to open completely (POP) at a specific pressure and to remain open until a specified pressure drop (BLOWDOWN) has occurred. Safety valves must close tightly. without chattering, and must remain tightly closed after seating.

To understand the difference between boiler safety valves and ordinary relief valves is important, The amount ofpressure required to lift a reliefvalve increases as the valve lifts, because the resistance of the spring increases in proportion to the amount of compression. When a relief valve is installed on a steam drum, it opens slightly when the specified pressure was exceeded; a small amount of steam is discharged; and then the valve closes again. Thus a relief valve on a steam drum is constantly opening and closing; this repeated action pounds the seat and disk and causes early failure of the valve. Safety valves are designed to open completely at a specified pressure to overcome this difficulty.

Several different types of safety valves are used on boilers; however, they all lift on the same general principle. In each case, the initial lift of the valve disk, or feather, is caused by static pressure of the steam acting upon the disk. or feather. As soon as the valve begins to open, however, a projecting lip, or ring, of the larger area is exposed for the steam pressure to act upon. The resulting increase in force overcomes the resistance of the spring. and the valve pops; that is, it opens quickly and completely. Because of the larger area now presented, the valve reseats at a lower pressure than that which caused it to lift originally.

Lifting levers are provided to lift the valve from its seat (when boiler pressure is at least 75 percent of that at which the valve is set to pop) to check the action and to blow away any dirt from the seat. When the lifting lever is used, raise the valve disk sufficiently to ensure that all foreign matter is blown from around the seat to prevent leakage after being closed.

The various types of safety valves differ chiefly as to the method of applying compression to the spring, the method of transmitting spring pressure to the feather, or disk, the shape of the feather. or disk, and the method of blowdown adjustment. Detailed information on the operation and maintenance of safety valves can be found in the instruction books furnished by the manufacturers of this equipment.

STEAM INJECTOR FEED SYSTEM

The STEAM INJECTOR (fig. 1- 12) is a boiler FEED PUMP that uses the velocity and condensation of a jet of steam from the boiler to lift and force a jet of water into

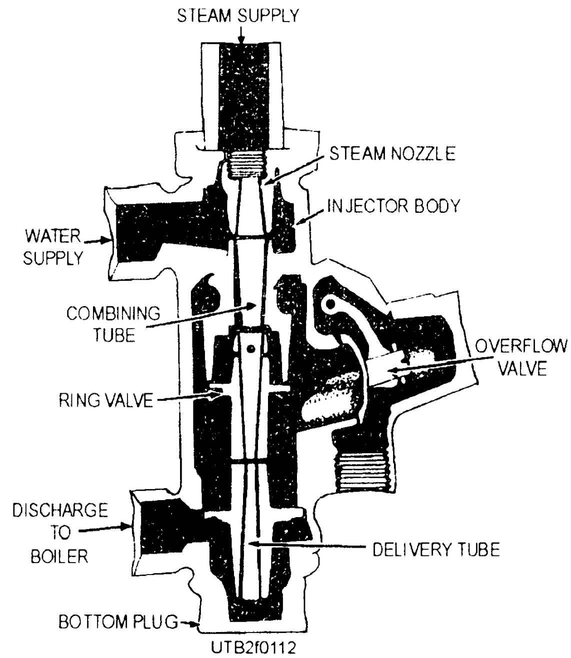


Figure 1-12.—A cross-sectional view of a steam injector.

the boiler. This injection of water is many times the weight of the original jet of steam.

The injector is used to some extent in boiler plants as an emergency or standby feed unit. It does not feed very hot water. Under the best conditions, it can lift a stream of water (that has a temperature of 120°F) about 14 feet.

The installation of an injector is not a difficult operation because the unit is mounted on the side of the boiler. The four connections (fig. 1-13) to the injector are as follows:

1. The discharge line to the boiler feedwater inlet

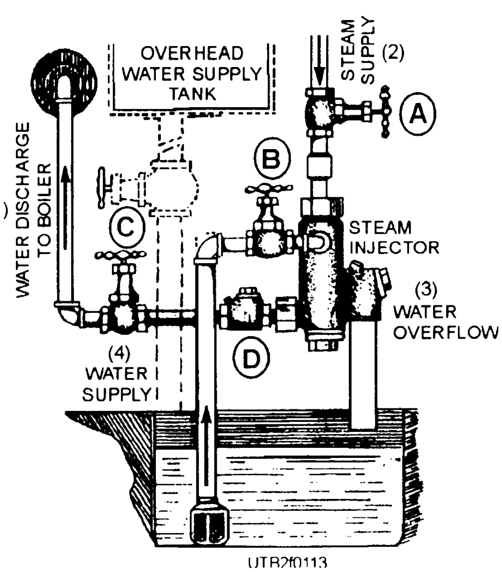


Figure 1-13.—Injector piping.

2. The steam supply line from the boiler

3. The water overflow line

4. The water supply line from the reservoir

The controls for the injector (fig. 1-13) include the following:

A. Steam supply valve

B. Water supply valve

C. Discharge valve to the boiler

D. Check valve in the discharge line

As you might expect. some degree of skill is needed to start the injector. After the injector begins to operate. however, it continues automatically until shutdown by the operator.

When starting the injector. first open the water supply valve (fig. 1-13B) about one full turn. Nest quickly turn the steam supply valve (fig. 1-13A) all the way open. At this point, steam rushes into the combining tube of the injector As the steam speeds past the water supply opening. it creates a suction that draws water through the opening into the combining tube. Water and steam are now mixed together inside the injector and the pressure opens a valve that leads to the boiler. Meanwhile. there is an excess of water in the injector; this excess is discharged through the overflow valve. As the nest step of the procedure, slowly turn the water supply valve (fig. 1-13B) toward the closed position until the overflow stops. The overflow valve has now closed and all of the water being picked up from the supply line is going into the boiler. Remember, this feedwater system is used on boilers only as a standby method for feeding water.

The water supply should not be hotter than 120°F for the injector to operate. When several unsuccessful attempts are made to operate the injector. it will become very hot and cannot be made to prime. When you should encounter this problem. pour cold water over the injector until it is cool enough to draw water from the supply when the steam valve is opened.

HANDHOLES AND MANHOLES

Handholds and manholes provide maintenance personnel access into a boiler to inspect and clean it internally as needed. These handholds and manholes will be covered in depth when boiler maintenance is discussed later in this volume.

BOILER ACCESSORIES

Figure 1-14 provides a graphic presentation of important boiler accessories. Refer to it as you study the table 1-2 which gives a brief description of each accessory, its location, and function.

Q9. Blowdown valves are installed at what location in a boiler?

Q10. How often should the fusible plugs in a boiler be renewed?

Q11. The two connections to the boiler of a water column are at what locations?

Q12. What are the three types of water level controls most often encountered by Seabees?

Q13. The electrode probe type of feedwater control has what total number of electrode sensors?

Q14. What boiler fitting is considered the most important?

Q15. What is the function of the guard valve on a boiler?

AUTOMATIC CONTROLS

Learning Objective: Identify the automatic controls commonly used on boilers and describe the function of each.

Automatic controls are a big asset since they reduce manual control of the furnace. boilers. and auxiliary equipment. For this reason. Utilitiesman personnel should be able to recognize and understand the basic operations of different types of boiler operating controls. The types of controls the Utilitiesman should become familiar with are as follows: float. pressure, combustion. flame failure. and operation controls.

FLOAT CONTROL

The float in a boiler control works on the same basic principle as the float in a flush-tank type of water closet. Float, or level, control depends on the level of fluid in a tank or boiler to indicate the balance between the flow out of and the flow into the equipment and to operate a controller to restore the balance.

A float is often used to measure the change in fluid level and to operate the controlled valve to restore the balance. It may be arranged to increase the flow when the fluid level drops. Figure 1-15 shows one of the methods used to accomplish this. Here, the float is connected to the control valve.

Table 1-2.—Boiler Accessories, Its Location, and Function

ITEM	ACCESSORY	LOCATION	PURPOSE
1	Boiler	Boiler room	Generate steam or hot water in a closed vessel
2	Main steam stop	On the steam outlet of a boiler	Place the boiler on line or off line
3	Guard valve	On the steam outlet of a boiler directly following the main steam-stop valve	Guard or backup to the main steam-stop valve
4	Daylight (drain) valve	Between the main steam-stop valve and the guard valve	Open only when the main steam and guard valves are closed. Indicates if one of the valves is leaking through
5	Main steam line	The line that conveys steam from a boiler to all branch or distribution lines. When a system is supplied by a bank of boilers connected into the same header, the line(s) conveying steam for the boiler(s) to the header	Carry steam from the boiler to the branches or distribution lines
6	Root valve	Installed in branch or distribution lines just off of the main steam line	Isolate a branch or distribution line (serves as an emergency shutoff)
7	Pressure regulating valve (PRV)	Installed as close as practical (after a reducing station) to the equipment or area it serves	Equipment that requires lower pressure than main steam line pressure (coppers, dishwashers, steam chest, turbines, etc.)
8	Steam trap	Installed on the discharge side of all steam heating or cooking equipment, dead ends, low points, or at regular intervals throughout a steam system (automatic drip legs)	Automatically drains condensate and prevents the passage of steam through equipment
9	Drip legs	Provided throughout a system where condensation is most likely to occur, such as low spots, bottom of risers, and dead ends	Remove condensate from a system manually

Table 1-2.—Boiler Accessories, Its Location, and Function—Continued

ITEM	ACCESSORY	LOCATION	PURPOSE
10	Temperature regulating valve (TRV)	Install in the steam supply line close to equipment needing temperature regulation (sensing element is installed at a point where the temperature is to be controlled, such as the hot- water discharge side of a heat exchanger	Control steam flow through a vessel or heating equipment
11	Heat exchanger	Locate as close as practical to the source for which it is going to supply heated water or oil	An unfired pressure vessel that contains a tube nest or electrical element. Used to heat oil or water
12	Strainer	Install in steam and water lines just ahead of PRVs, TRVs, steam traps, and pumps	Prevent malfunctions or costly repairs to equipment and com- ponents by trapping foreign matter, such as rust, scale, and dirt
13	Condensate line	Return line extends from the discharge side of steam traps to the condensate/makeup feedwater tank	Carry condensed steam back through piping for reuse in the boiler or heating vessel
14	Condensate/makeup tank	Close to the boiler as practical and at a higher level than the boiler feed-pump suction line	Provide storage space for condensate and makeup/feedwater and vent noncondensable gases to the atmosphere
15	Feed pump	Supplies water to the boiler as required	Installed between the condensate/ makeup/feedwater tank and the boiler sheall or steam drum
16	Feedwater pipe	This line extends from the discharge side of the feedwater pump to the boiler shell or drum (installed below the steaming water level)	Provide feedwater to the boiler when required
17	Relief valve	Between the feed pump and the nearest shutoff valve in the external feed line	Relieve excessive pressure should the external feed line be secured and the feed pump started accidently. A ruptured line or serious damage to the feed pump could occur if there were no relief valve
18	Feed check valve	Between the feed pump and the stop valve in the feed-water pipe	Prevent backflow from the boiler through the feedwater line into the condensate/feedwater tank during the off cycle of the pump
19	Feed stop valve	In the feedwater line as close to the boiler as possible between the boiler and feed check valve	Permit or prevent the flow of water to the boiler

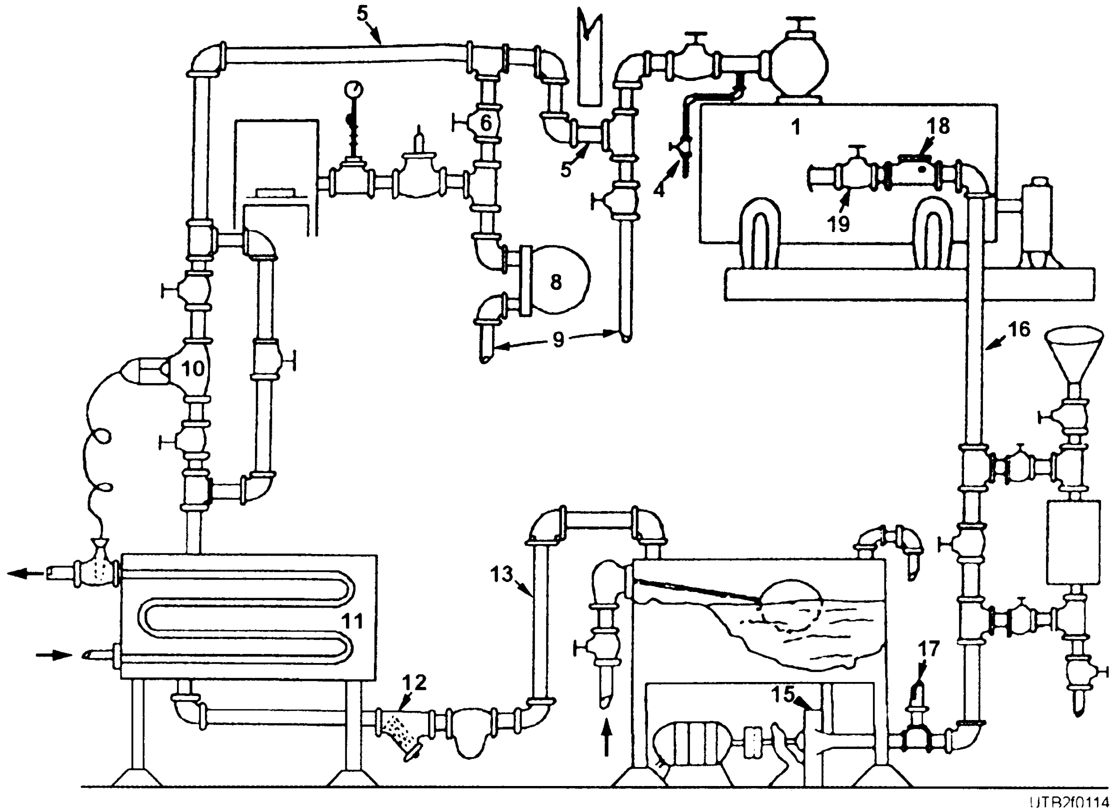


Figure 1-14.—Boiler accessory equipment.

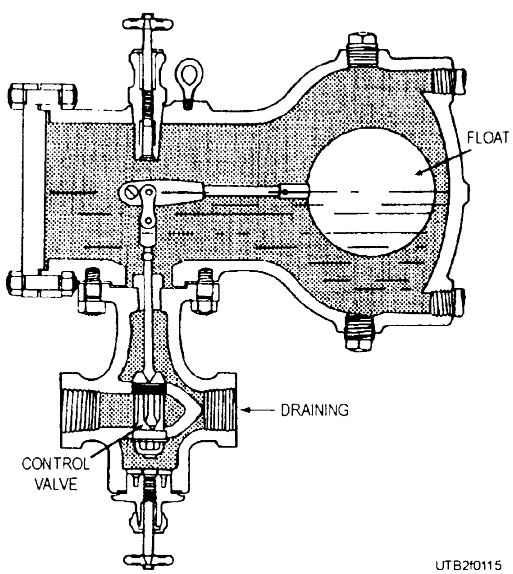


Figure 1-15.—Float controller.

PRESSURE-REGULATING CONTROL

Pressure regulating is the process of maintaining a difference of pressure between two points in a system. One type of pressure regulating maintains a definite pressure in one part of the system, while the other part fluctuates or changes within certain limits. An example of this type of control is a pressure-regulator valve (fig. 1-16) that maintains a definite pressure on the discharge side of the valve by controlling the flow of steam, air, or gas through the valve.

A second type of regulator maintains a definite difference in pressure between two points and also controls the flow. This type of regulator is often applied to a boiler feeding to maintain a fixed difference between the pressure of water supplied at the feed valve and the pressure in the boiler steam drum. The pressure regulator may consist of a self-contained device that operates the regulating valve directly, or it may consist of a pressure-measuring device, such as a Bourdon-tube gauge, that operates a pilot or relay valve. The valve positions the regulating valve or mechanism to maintain the desired conditions.

Pressure controls (fig. 1-17) are designed primarily for steam-heating systems but are also available for controlling air, liquids, or gases that are not chemically injurious to the control. The function of the pressure control is as follows:

- To control the pressure in the boiler

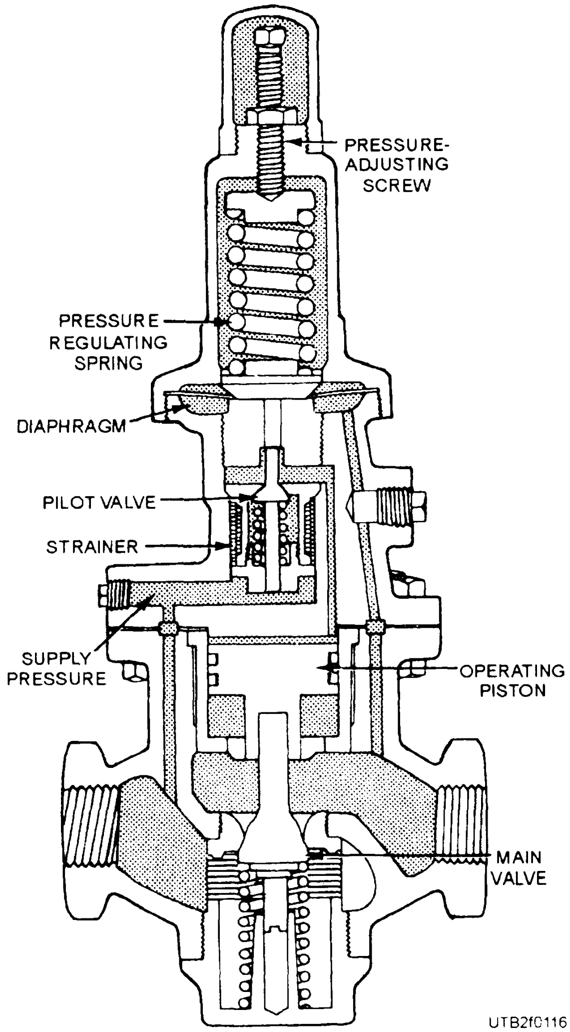


Figure 1-16.—Pressure regulator.

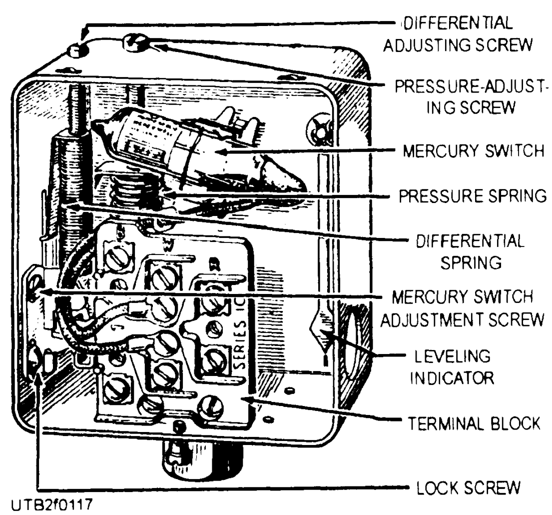


Figure 1-17.—Typical pressure control with a differential from 0 to 10 pounds.

- To secure the fuel-burning equipment when the pressure reaches a predetermined cutout
- To start the fuel-burning equipment when the pressure drops to the cut-in point

There are two settings on the pressure control—the cut-in point and the differential. To find the cut-out point, you add the differential to the cut-in pressure; for example, when you were operating a boiler with a cut-in pressure of 90 pounds and a differential of 13 pounds, the cut-out pressure should be 103 pounds. When excessive vibrations are encountered, you should mount the pressure control remotely from the boiler on a solid mounting with a suitable piping connection between them. When a mercury type of switch control is used, be sure that it is mounted level and that the siphon (pigtail) has the loop extending in the direction of the back of the control and at a 90-degree angle to the front, as shown in figure 1-18. This position prevents expansion and contraction of the siphon from affecting the mercury level and accuracy of the control. Additionally, when you install any pigtail, ensure the tube is filled with water. The water will prevent hot steam from contacting the control.

The pressure control can be mounted either on a tee along with the pressure gauge on the pressure-gauge tapping, as shown in figure 1-18, or it can be mounted on the low-water cutout provided by some manufacturers. In either case, be sure that the pipe dope does NOT enter the control. The procedure you should follow is to apply the dope to the male threads, leaving the first two threads bare.

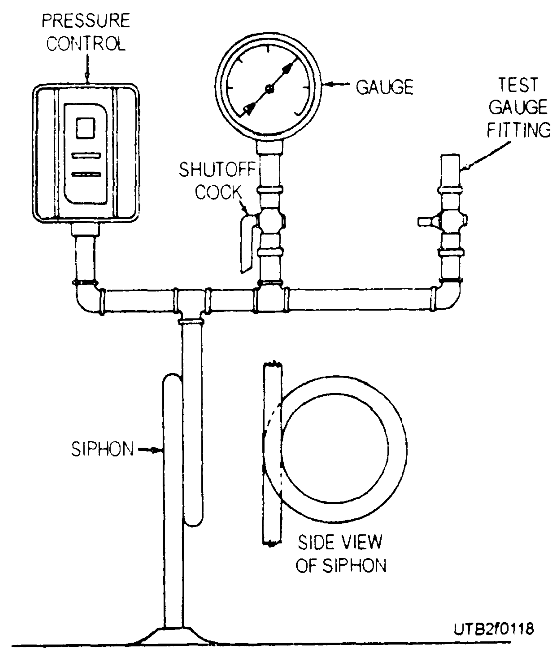


Figure 1-18.—A typical steam gauge installation.

COMBUSTION CONTROL

Combustion control is the process of regulating the mixed flow of air and fuel to a furnace as necessary to supply the demand for steam. A modulating pressuretrol controls the movement of the modutrol motor which, in turn. opens or closes the oil valve and air shutters to adjust the rate of firing to suit the demands of the boiler.

A modulating motor (fig. 1-19) consists of the motor windings, a balancing relay, and a balancing potentiometer, The loading is transmitted to the winding through an oil-immersed gear train from the crank arm. The crankshaft is the double-ended type, and the crank arm may be mounted on either end of the motor. The motor works with the potentiometer coil in the modulating pressuretrol. An electrical imbalance is created by pressure change signals to the pressuretrol. This causes the motor to rotate in an attempt to rebalance the circuit. The crank arm, through linkage, positions the burner air louvers and the oil regulating valve, maintaining a balanced flow of air and oil throughout the burner firing range.

Another process of controlling, combustion air is to use a manually adjusted air damper. A centrifugal blower, mounted on the boiler head and driven by the blower motor, furnishes combustion air. A definite amount of air must be forced into the combustion chamber to mix with the atomized oil to obtain efficient combustion. In operation, a pressure is built up in the entire head and the secondary air is forced through a diffuser to mix thoroughly with the atomized oil as combustion takes place.

The combustion airflow diagram in figure 1-20 shows a cutaway view of those components that influence most the path of the air through the burner assembly. Air is drawn into the motor-driven blower through the adjustable air damper at (A) and forced through openings (B) into the air box. Sufficient pressure is built up to force the air through openings (C) and the diffusor (D). In the area immediately beyond the diffusor (D), combustion is completed. The hot gaseous products of combustion are forced on through the remaining three passes where they give up a large portion of the heat contained to the water which completely envelopes the passes.

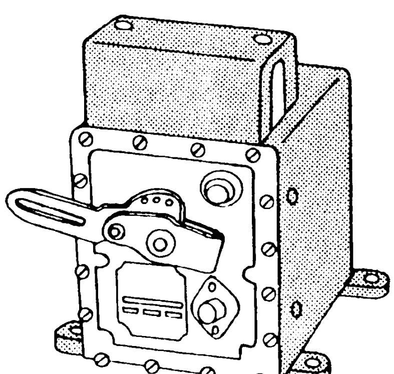


Figure 1-19.—A modulating motor.

The rate at which combustion air is delivered can be changed by throttling the intake to the blower by opening or closing the air damper to obtain the exact rate of airflow required for complete combustion. Since the rate at which fuel is delivered is predetermined by the design and is not readily adjustable, setting of the air damper is the only means of obtaining the correct ratio of fuel to air to ensure the most efficient combustion.

A pressure-regulating valve is built into the pump that controls the fuel. The fuel pump (fig. 1-21) contains a two-stage gear-type pump, a suction strainer, a pressure-regulating valve, and a nozzle cutoff valve, all assembled in a single housing. Knowledge of the functional relationship of the component parts can be gained by studying the internal oil flow diagram shown in figure 1-22. Observe that the two-stage fuel unit consists essentially of two pumps operating in tandem and arranged in a common housing. The first stage develops a pressure below the atmospheric pressure level at its inlet that causes the oil to flow from storage or supply to the strainer chamber reservoir. All air drawn into the unit rises to the top of this chamber. This air and excess oil are drawn into the first-stage-pumping element and pumped back to the fuel oil storage tank. The second stage withdraws air-free oil from the strainer chamber reservoir and raises the oil pressure to that required for proper atomization at the burner nozzles. The second stage, operating against a combination pressure regulating and nozzle cutoff valve, develops atomizing pressure because of the flow restriction imposed by this valve. The pressure-regulating valve also bypasses excess second-stage oil back to the bottom of the strainer chamber reservoir. The atomizing pressure can be varied within a restricted range by adjustment of the spring-loaded pressure-regulating valve. Normal atomizing pressures generally range between 95 and 120 pounds per square inch.

An orifice is included in the fuel line to the main oil burner. as shown in figure 1-22. The orifice serves to keep the oil pressure from experiencing a sudden drop when the solenoid oil valve in that line opens. The orifice is commonly built into the solenoid oil valve (fig. 1-22, item 1). Included in the schematic diagram is a photocell

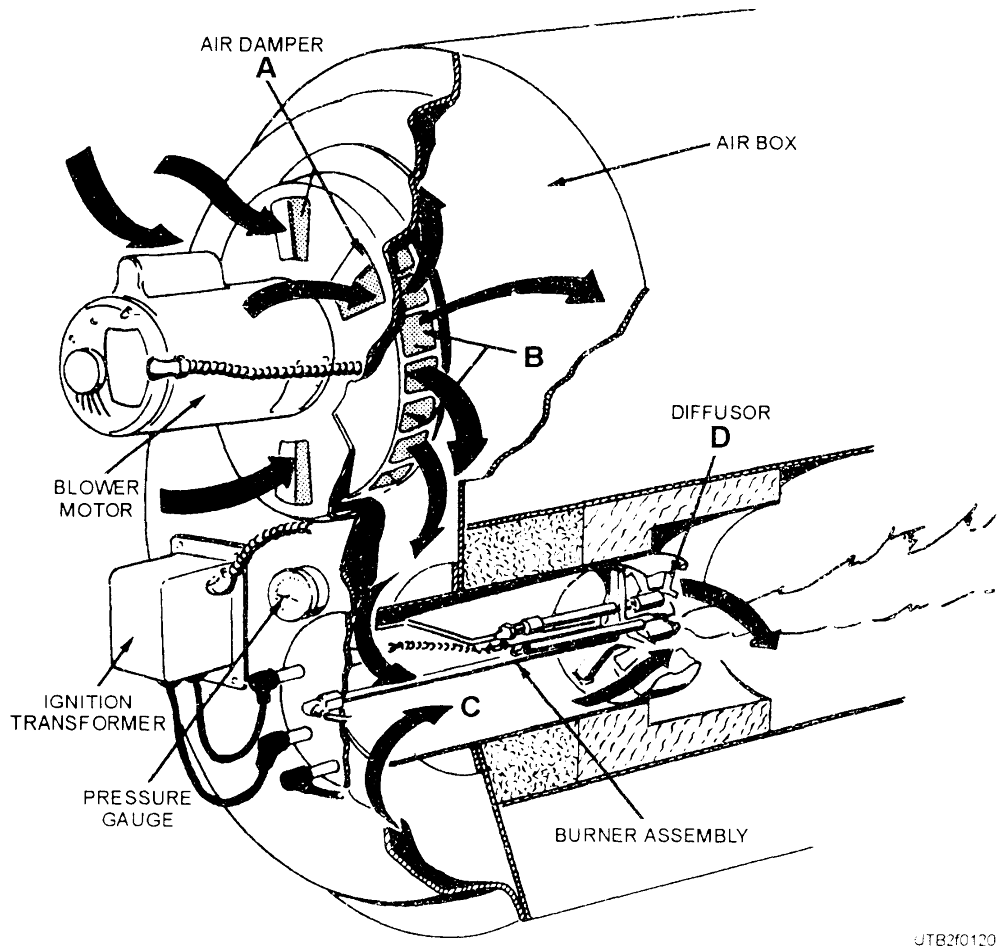


Figure 1-20.—Airflow diagram.

(3) which, if it sights no flame, reacts to cause a switching action that results in shutting down the burner.

FLAME FAILURE AND OPERATIONAL CONTROLS

Frequently on fully automatic boilers, you will find an electronic type of device provided for the control of flame failure. The device provides automatic start and operation of the main burner equipment. Some controls are designed to close all fuel valves, shut down the burner equipment within 4 seconds after a flame failure. and actuate an alarm. Some controls also create a safety shutdown within 4 seconds after de-energization of ignition equipment when the main burner flame is not properly established or fails during the normal starting sequence. These controls must create a safety shutdown when the pilot flame is not established and confirmed within 7 seconds after lighting. A safety shutdown requires manual reset before operation can be resumed and prevents recycling of the burner equipment.

Q16. What is the process of maintaining a difference of pressure between two points in a system called?

Q17. The flow of the air-fuel mixture supplied to the furnace is regulated by steam demand. What is this process called?

Q18. The rate at which combustion air is delivered to the blower can be changed by throttling what device?

Q19. Once a safety shutdown of a boiler has occurred, what action must be taken before operations can resume?

INSTRUMENTS AND METERS

Learning Objective: Identify the instruments and meters used on boilers and describe the function of each.

A pressure gauge is essential for safe operation of a boiler plant. However, the use of additional instruments.

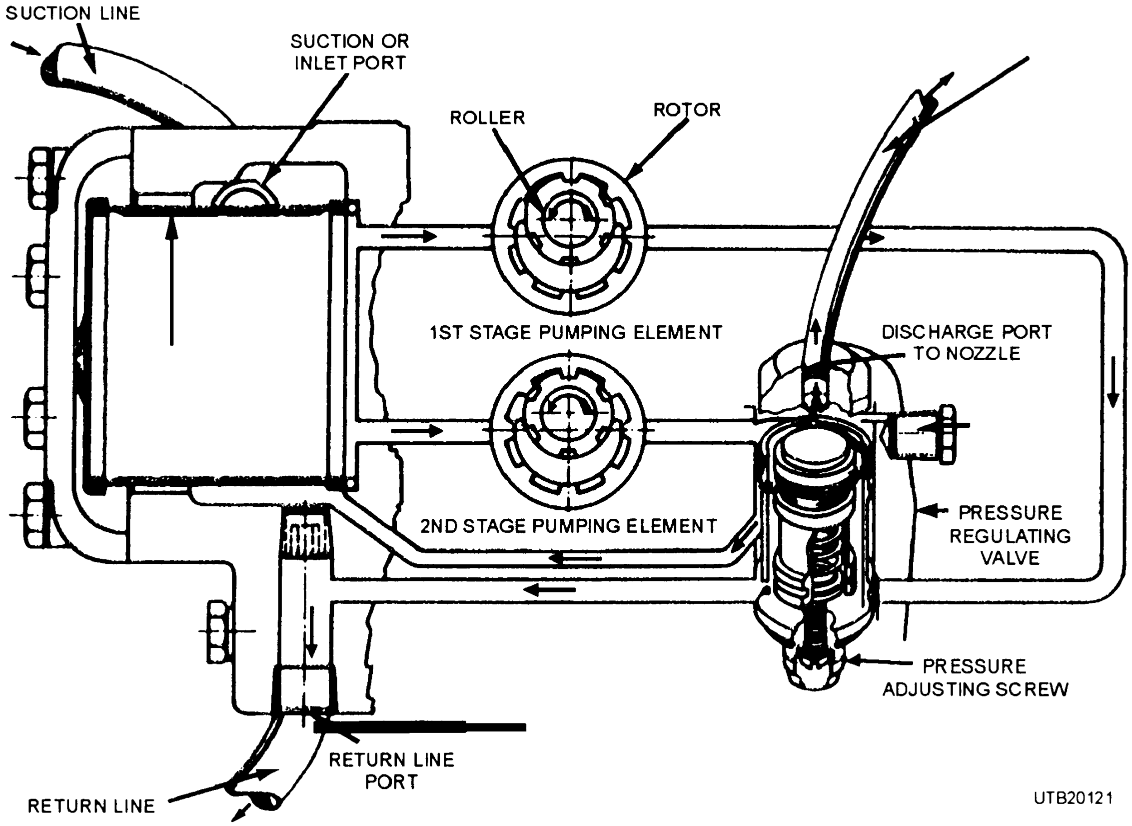


Figure 1-21.—Fuel oil pump.

such as flowmeters and draft gauges, increases safety and promotes efficiency. All of these instruments may be either indicating or recording.

STEAM FLOWMETERS

A Utilitiesman must be able to identify the different types of monitoring instruments and understand their operation and use. Meters used to measure quantities are divided into two general types:

1. Those indicating rate, such as flowmeters
2. Those indicating the total, such as scales

Many devices are designed to measure and indicate the pressure of steam flow. One of these devices is shown in figure 1-23. This meter uses a weighted inverted bell (called a Ledoux bell) sealed with mercury. The bell moves up and down as the rate of flow changes. The movement is transmitted to a pen that records the flow.

STEAM AND AIR FLOWMETERS

A combustion air and steam flowmeter is shown in figure 1-24. This meter is used as a guide in controlling the relationship between air required and air actually supplied to burn the fuel. The rate of steam generation is used as a measure of air necessary to burn the required amount of fuel. The flow of gases through the boiler setting is used as a measure of air supplied.

The essential parts of the meter are two airflow bells supported from knife-edges on a beam, which is supported by other knife-edges, and a mercury displacer assembly supported by a knife-edge on the beam. The bottoms of the bells are sealed with oil, and the spaces under the bells are connected to two points of the boiler setting.

DRAFT GAUGES

A draft gauge is a form of pressure gauge. In boiler practice, the term *draft* usually refers to the pressure difference producing the flow. Drafts are pressures below atmospheric pressure. They are measured in inches of water. A draft gauge is essential to boiler operation. Its use increases the safety of operation.

A simple type of draft gauge is the U-tube gauge. The source of draft is connected to one leg of the U and the other end is left open. The difference between the levels of the liquid in the two legs is a measure of the draft. Water is generally used in this type of gauge. Take

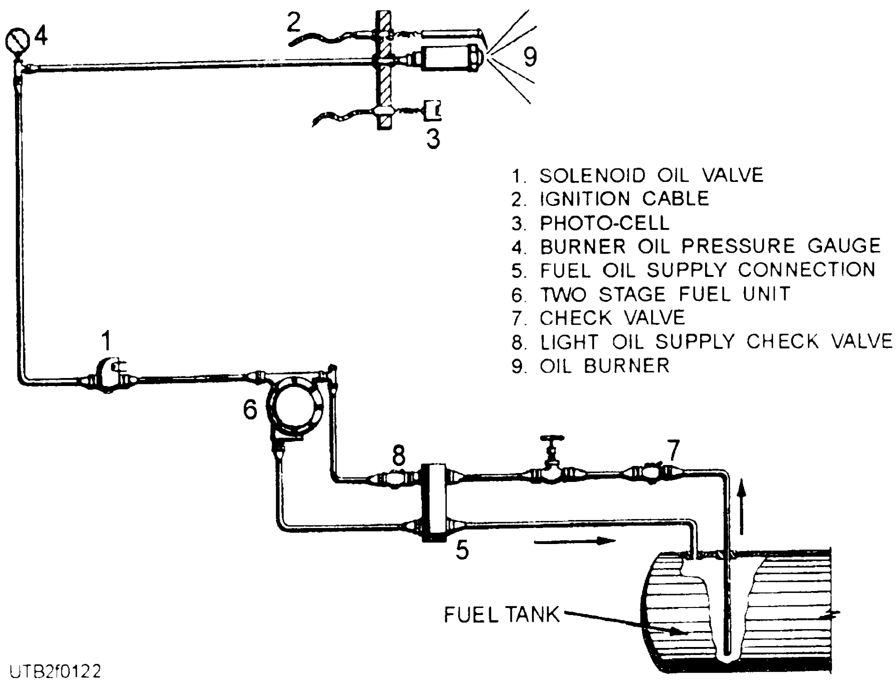


Figure 1-22.—The internal oil flow diagram.

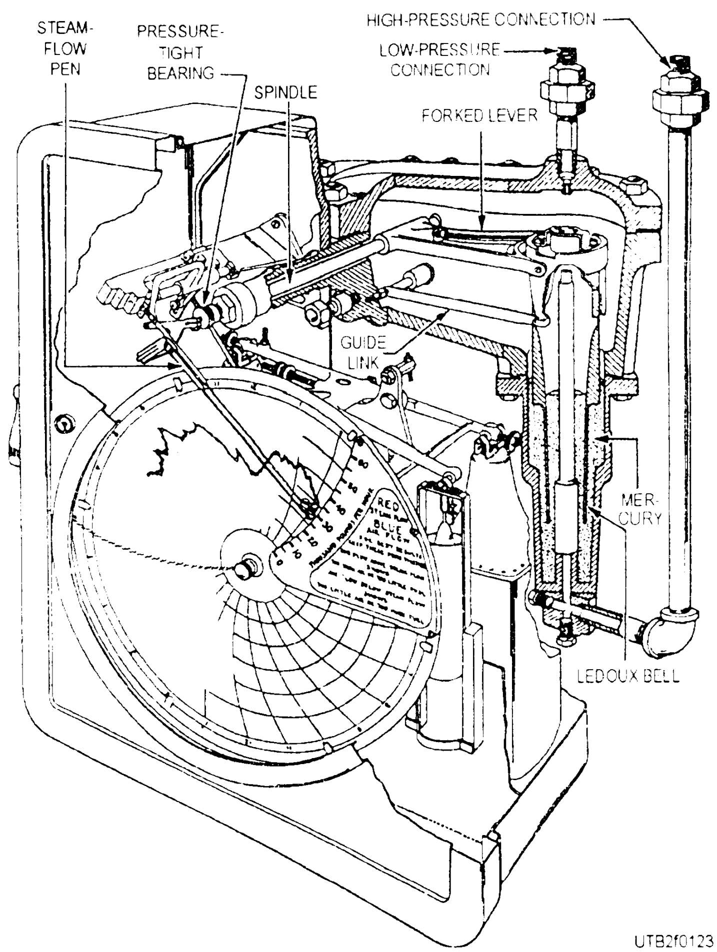


Figure 1-23.—Flowmeter.

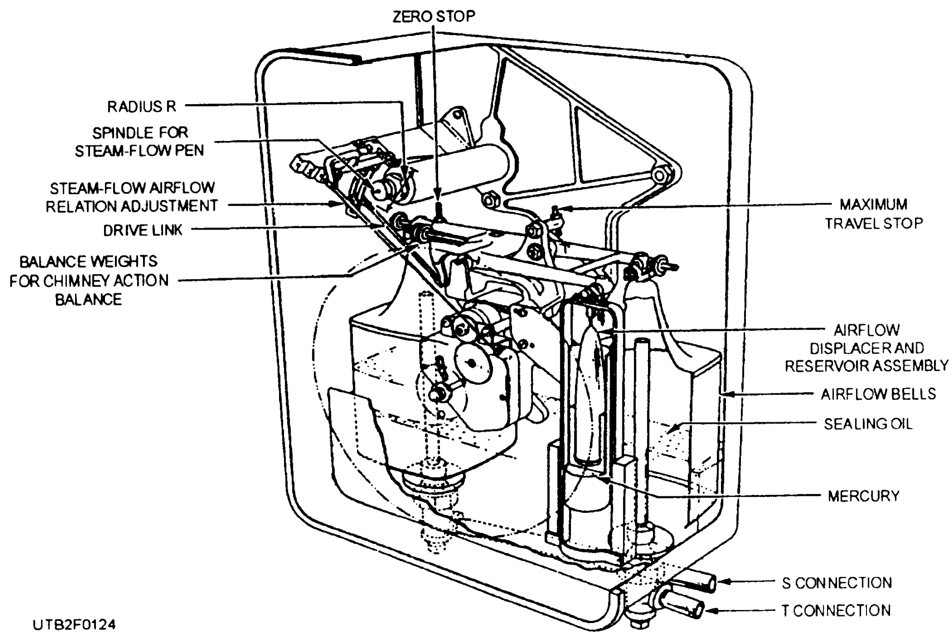


Figure 1-24.—Airflow mechanism of a boiler air flowmeter.

a close look at figure 1-25 that shows a comparison of an inclined-draft gauge and a U-tube gauge.

When one leg of the U tube is arranged on an incline, the distance moved by the liquid in the inclined portion is increased for a given draft change which makes more accurate reading possible.

Two or more draft gauges are required for economical boiler operation. The gauges inform the operator of the relative amount of air being supplied to burn the fuel and the condition of the gas passages. Draft gauges are made as indicators, recorders, or both. The measuring element uses a column of liquid, a diaphragm,

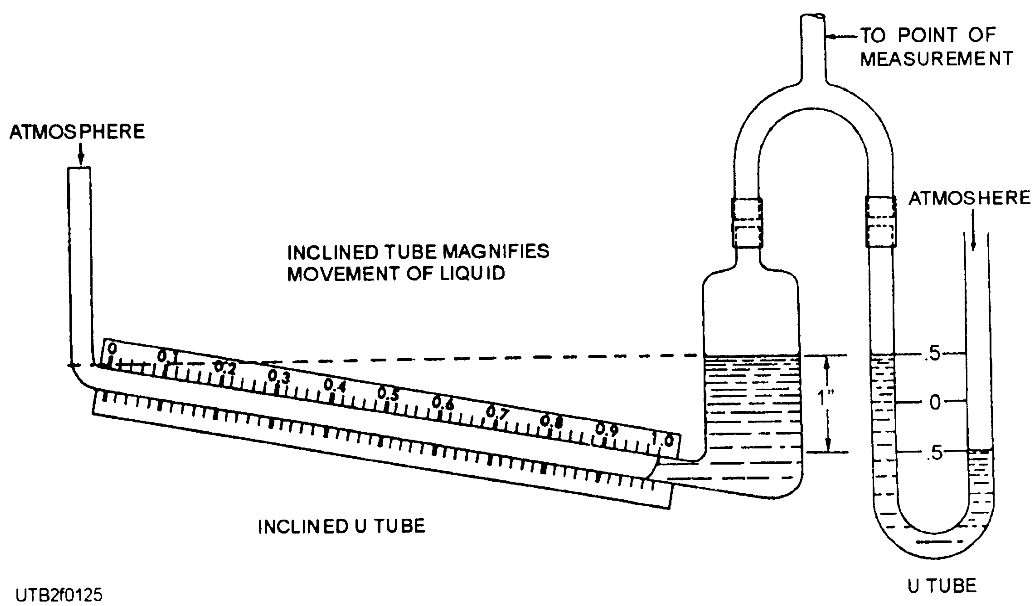


Figure 1-25.—Comparison of inclined-draft gauge and U-tube gauge.

or a bellows. The liquids used are oil, water, or mercury. The gauge shown in figure 1-26 is an indicating type that operates on the same principle as the U tube (difference between the levels of the liquid in the two legs is a measure of the draft).

The bottom of the inverted bell is sealed with oil or mercury, depending on the magnitude of the draft or pressure to be measured. It is supported by knife-edges on the beam to reduce friction as much as possible. The weights counterbalance the weight of the bell. and the pointer is returned to zero. The source of draft is connected to the tube, which projects into the inverted bell, so an increase in draft causes the pointer to move down.

CO_2 METERS (ANALYZERS)

Figure 1-27 shows one type of carbon dioxide meter. The meters are also known as analyzers and are designed for determining, indicating, and recording the percentage of CO_2 (carbon dioxide) in the products of combustion. The principle of this instrument is based on the fact that the specific weight of flue gas varies in proportion to its CO_2 content (CO_2 being considerably heavier than the remaining parts of the flue gas).

Q20. Meters are divided into what two general categories?

Q21. In reference to boiler operations, what does the term "draft" mean?

BOILER WATER TREATMENT AND CLEANING

Learning Objective: Describe the methods and procedures for the testing of and treatment of boiler water.

A Utilitiesman must understand the methods, tests, and safety precautions involved in boiler water treatment and the procedures for cleaning boiler firesides and watersides. To ensure a boiler operates at peak efficiency, you must treat and clean it. Water testing, treatment. and cleaning go hand-in-hand. The reason for this is because the effect of the impurities in the water on interior surfaces determines the method and frequency of boiler cleaning. In this section, we will discuss the relationships between water testing. treatment. and cleaning and the procedures for each.

WATER IMPURITIES

All natural waters contain acid materials and scale-forming compounds of calcium and magnesium that attack ferrous metals. Some water sources contain more scale-forming compounds than others; therefore, some waters are more corrosive than others. Subsurface or well waters are generally more scale-forming, while surface waters are usually more corrosive. To prevent scale formation on the internal water-contacted surfaces of a boiler and to prevent destruction of the boiler metal by corrosion, chemically treat feedwater and boiler

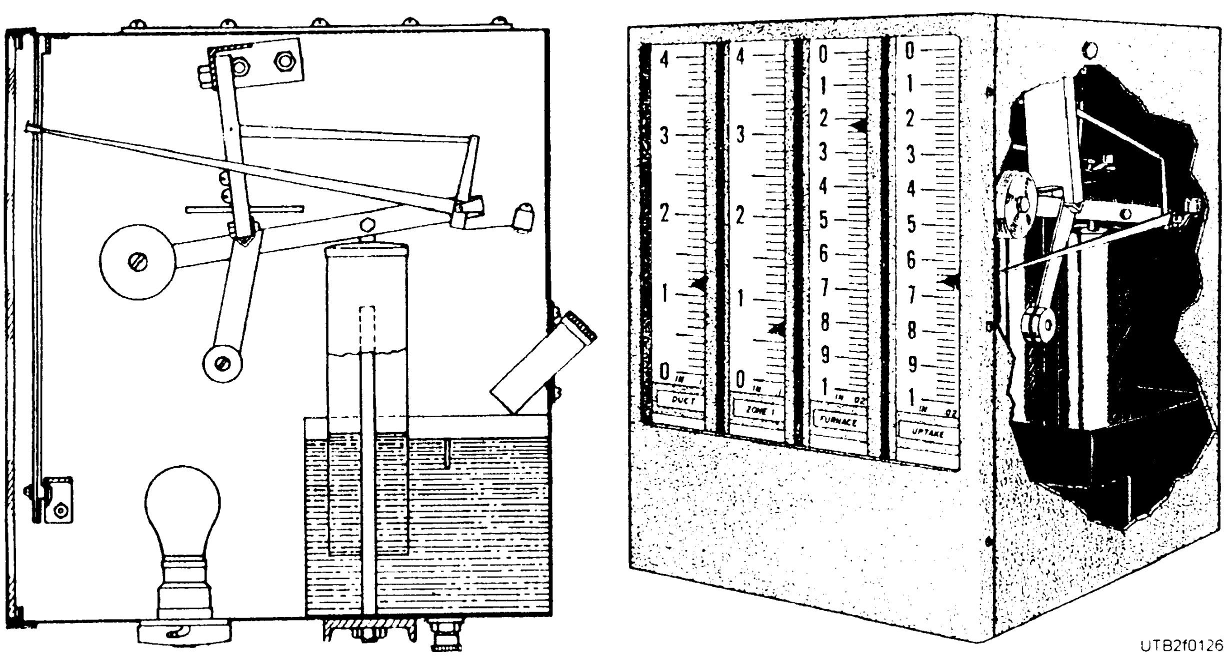
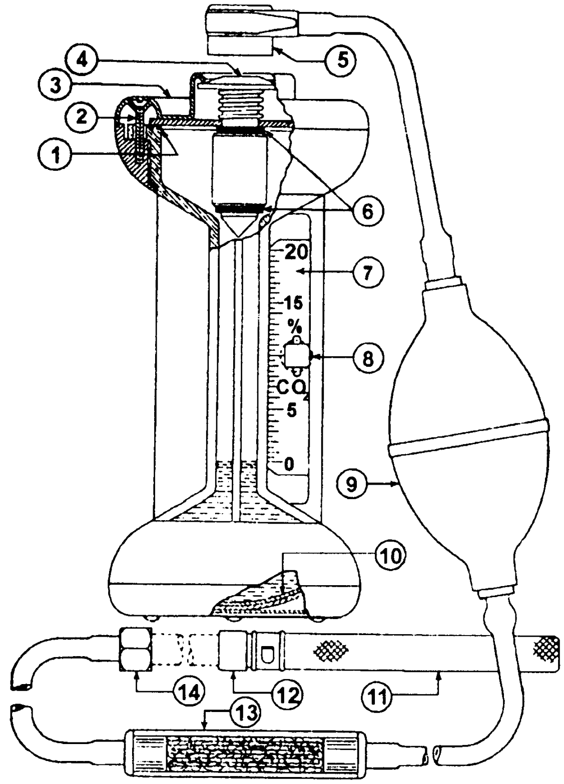


Figure 1-26.—Liquid-sealed draft gauge.



1. GASKET
2. TOP CAP HOLDING SCREW.
3. TOP CAP
4. PLUNGER CAP
5. CONNECTOR TIP.
6. PLUNGER SEATS.
7. CO_2 SCALE.
8 SCALE LOCKING SCREW.
9. RUBBER ASPIRATOR BULB
10. BOTTOM OF ANALYZER.
11. FILTER NIPPLE.
12. CONNECTION SAMPLING TUBE TO FILTER NIPPLE.
13 FILTER TUBE.
14. CONNECTION TUBING TO SAMPLING TUBE.

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Figure 1-27.—CO_2 meter (analyzer).

water. This chemical treatment prolongs the useful life of the boiler and results in appreciable savings in fuel, since maximum heat transfer is possible with no scale deposits.

SCALE

Crystal clear water, satisfactory for domestic use, may contain enough scale-forming elements to render it harmful and dangerous in boilers. Two such scale-forming elements are precipitates of hardness and silica.

Scale deposited on the metal surfaces of boilers and auxiliary water heat exchange equipment consists largely of precipitates of the HARDNESS ingredients—calcium and magnesium and their compounds. Calcium sulfate scale is, next to silica, the most adherent and difficult to remove. Calcium and magnesium carbonates are the most common. Their removal requires tedious hand scraping and internal cleaning by power-driven wire brushes. When deposits are thick and hard, the more costly and hazardous method of inhibited acid cleaning must be used. Scale deposits are prevented by the following: removal of calcium and magnesium in the feedwater to the boiler (external treatment); chemical treatment of boiler water (phosphate, organic extracts, etc.); and changing scale-forming compounds to form soft nonadherent sludge instead of scale that can be easily removed from the boiler by blowdown (internal treatment).

SILICA in boiler feedwater precipitates and forms a hard, glossy coating on the internal surfaces. In the feedwater of high-pressure boilers, such as those used in electric generating plants, a certain amount of silica vaporizes under the influence of high pressure and temperature. The vapor is carried over with steam and silica deposits on the intermediate and low-pressure blading of turbines. In boilers operating in the range of 10- to 125-psig pressure, the silica problem is not so troublesome. When the water is low in hardness, contains phosphate that prevents calcium silicate scale from forming, or has enough alkalinity to keep the silica soluble. no great difficulty is encountered. The amount of soluble silica can be limited by continuous or routine boiler blowdown to prevent buildup of excessive concentrations.

CORROSION

Corrosion control occurs with the problem of scale control. Boilers, feedwater heaters, and associated piping must be protected against corrosion. Corrosion results from water that is acidic (contains dissolved oxygen and carbon dioxide). Corrosion is prevented by removing these dissolved gases by deaeration of feedwater, by neutralizing traces of dissolved gases in effluent of the deaerating heater by use of suitable chemicals. and by neutralizing acidity in water with an alkali.

METHODS OF TREATMENT

The specific method of chemical treatment used varies with the type of boiler and the specific properties of the water from which the boiler feed is derived. In general, however, the chemical treatment of feedwater and boiler water is divided into two broad types or methods-external treatment and internal treatment of makeup water for alkalinity control and for removal of scale-forming materials and dissolved gases (oxygen and carbon dioxide) before the water enters the boiler. "Internal treatment" means that chemicals are put directly into the boiler feedwater or the boiler water inside the boiler. Frequently, both external and internal chemical treatments are used.

External treatment. frequently followed by some internal treatment, often provides better boiler water conditions than internal treatment alone. However, external treatment requires the use of considerable equipment, such as chemical tanks, softening tanks, filters, or beds of minerals, and the installation costs are high. Such treatment is therefore used only when the makeup water is so hard or so high in dissolved minerals or when internal treatment by itself does not maintain the desired boiler water conditions. What is the dividing line between the hardness and the concentration of dissolved matter in water? What factors other than the dividing line determine the need for external treatment? These factors are the physical makeup of the plant. the type and design of the boilers used, the percentage of makeup water being used, the amount of sludge the boiler can handle, the space available, and the adaptability of the operators. Many methods of INTERNAL TREATMENT are in use. Most of these treatments use carefully controlled boiler water alkalinity, an alkaline phosphate, and organic material. One of the organic materials used is tannin. Tannin is a boiler water sludge dispersant; that is, it makes precipitates more fluid and prevents their jelling into masses that are difficult to remove by blowdown. Because of treatment costs and simplicity of chemical concentration control, the alkaline phosphate-tannin method of internal treatment is perhaps the most widely used. When properly applied and controlled, this treatment prevents formation of scale on internal boiler surfaces and prevents corrosion of the boiler tubes and shell.

BOILER WATER TESTING

As we have just seen. boiler water must be treated with chemicals to prevent the formation of scale on the internal surface of the boiler and to prevent deterioration of the boiler metal by corrosion. Boiler water must be tested to determine the sufficiency of chemical residuals to maintain clean boiler surfaces. As a Utilitiesman, you should be able to make various boiler water tests (fig. 1-28). The procedures for a few types of tests that you may have to make is given here—tests for hardness. phosphate. tannin. caustic alkalinity (with and without tannin), sodium sulfite, and pH. A test kit is provided for the different tests. Each test kit contains the equipment and materials for the specified test. If a kit is not available, you have to use the laboratory equipment (figs. 1-29 and 1-30) provided in the boiler or water treatment plants.

Figure 1-28.—Testing boiler water is an important job.

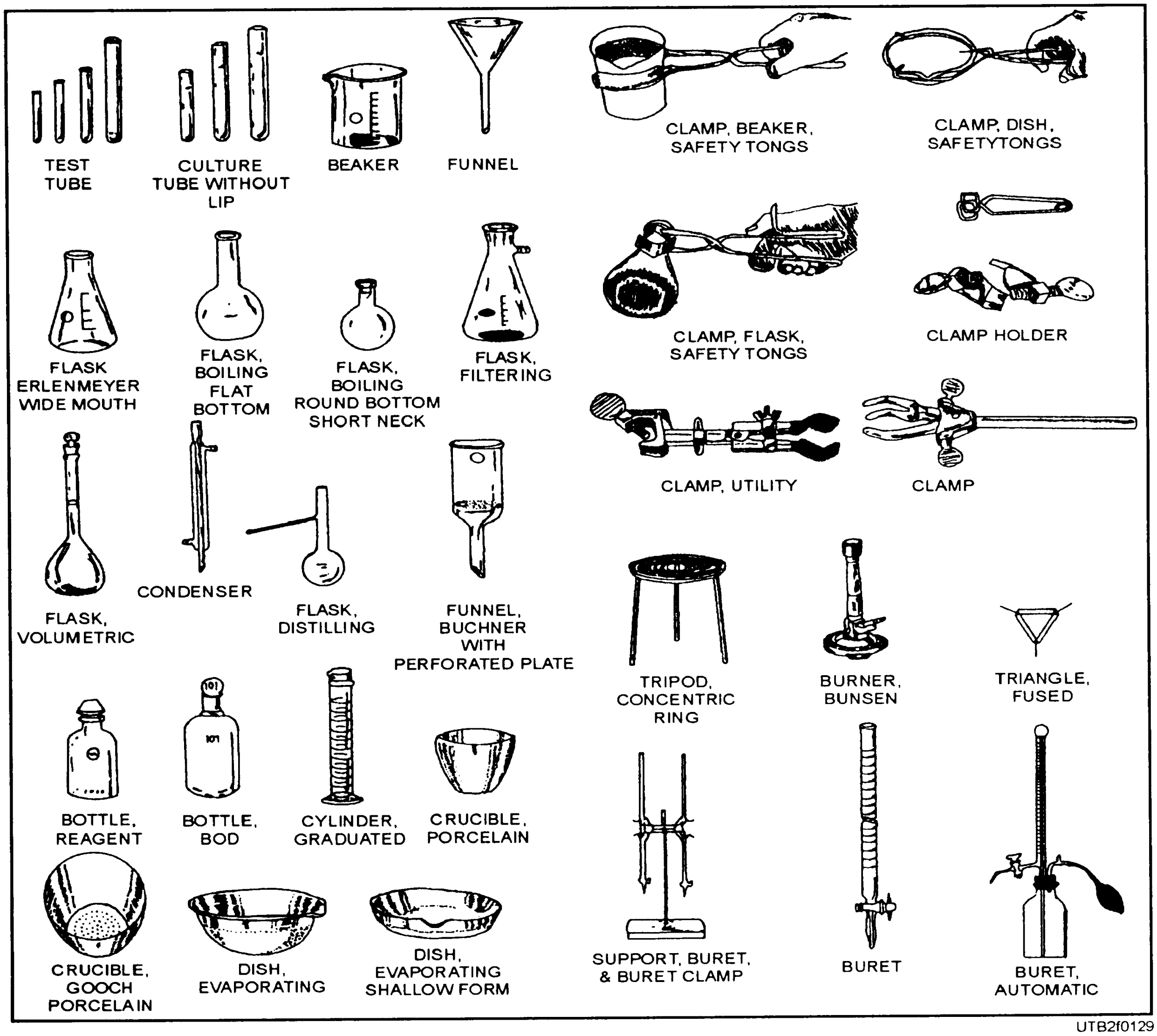

Figure 1-29.—General laboratory equipment.

CAUTION

The following caution applies to each test that is discussed: IF THE TESTING PROCEDURES OF THE EQUIPMENT AND/OR REAGENT SUPPLIER DIFFERS FROM THAT PRESCRIBED IN THIS TEXT, THE SUPPLIER'S PROCEDURE SHOULD BE USED.

Test for Hardness

Boilers operating at pressures of 15 psi and less are normally used for space heating and hot-water generation. Practically all the condensate is returned to the plant. Only a small amount of makeup is required, and secondary feedwater treatment usually is sufficient. When appreciable quantities of steam are used in process work and not returned as condensate to the plant, the problem of scaling and corrosion arises, and more

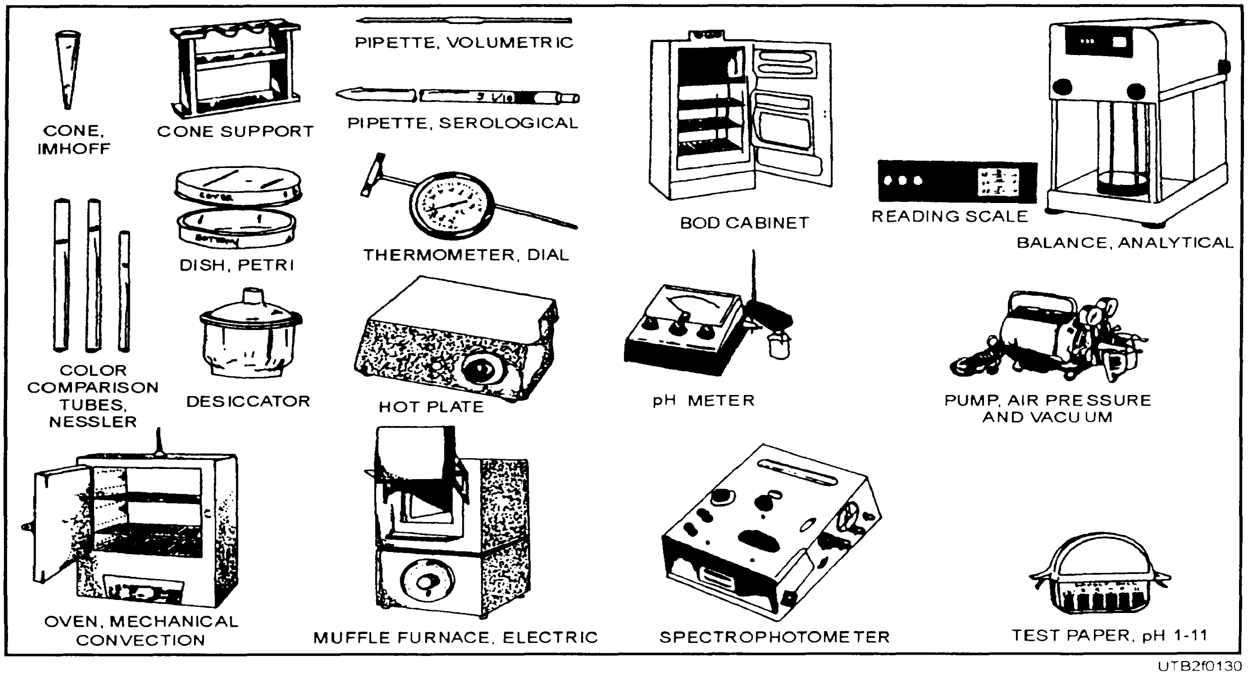

Figure 1-30.—General laboratory equipment.

complete treatment of feedwater must be considered. The ideal water for boilers does not form scale or deposits. does not pit feedwater systems and boiler surfaces, and does not generate appreciable CO_2 in steam. However. such raw makeup water is impossible to get in the natural state from wells or surface sources. Does the advantage of treatment make up for the cost of treatment?

Feedwater of 20- to 25-ppm hardness as calcium carbonate ($CaCO_3$) need not be treated externally to reduce hardness if enough alkalinity is present to precipitate the hardness in the boiler as $CaCO_3$, or if hardness reducers, such as phosphates, are introduced to combine with and precipitate the hardness. Precipitation of this hardness in a low- or medium-pressure boiler generally does not cause wasteful blowdown. When the mixture ofcondensate and makeup in a medium-pressure steam plant has a hardness greater than 20 to 25 ppm as $CaCO_3$, the hardness should be reduced to a level of 0 to 2 ppm as $CaCO_3$.

Feedwater of a hardness in excess of 2 ppm as $CaCO_3$ should be treated to bring it within the range of 0 to 2 ppm as $CaCO_3$. This small remaining hardness can be precipitated in the boiler by secondary treatment and removed by continuous blowoff equipment.

The test for hardness, as presented here, uses the calorimetric titration method. This test is based on finding the total calcium and magnesium content of a sample by titration with a sequestering agent in the presence of an organic dye sensitive to calcium and magnesium ions. The end point is a color change from red to blue, which occurs when all the calcium and magnesium ions are separated.

The following equipment is used for the hardness test:

- One 25-ml buret, automatic, complete
- One 210-ml casserole, porcelain
- One 50-ml cylinder, graduated
- One stirring rod, glass

The reagents for the test are as follows:

- Hardness indicator

- Hardness buffer
- Hardness titrating solution

The steps of the hardness test are as follows:

1. Measure 50 ml of the sample in the graduated cylinder and transfer it to the casserole.
2. With the calibrated dropper, add 0.5 ml of the hardness buffer reagent to the sample, and stir.
3. Add 4 to 6 drops of hardness indicator. If hardness is present, the sample will turn red.
4. Add the hardness titrating solution slowly from the burette, and stir continually. When approaching the end point, note that the sample begins to turn blue, although you can still see a definite reddish tinge. The end point is the final discharge of the reddish tinge. Adding more hardness titrate solution does not produce further color change.

In using this procedure, add the hardness titrating solution slowly because the end point is sharp and rapid. For routine hardness determination, measure 50 ml of the sample, but add only approximately 40 to 45 ml to the casserole at the start of the test. The hardness buffer reagent and the hardness indicator should then be added as directed and the mixture titrated rapidly to the end point. The remaining portion of the sample should then be added. The hardness in the remainder of the sample will turn the contents of the casserole red again. Titrating is continued slowly until the final end point is reached. A record should be kept of the total milliliters of hardness titrating solution used.

To calculate the results in ppm hardness, use the following equation:

ppm hardness = ml titrating solution x 1,000

($CaCO_3$) (ml sample)

With a 50-ml sample, the hardness in ppm as $CaCO_3$ is equal to the ml of titrating solution used, multiplied by 20.

Test for Phosphate

The calorimetric test for phosphate uses a decolorizing carbon to remove tannin. Carbon absorbs the tannin, and the carbon and tannin are then filtered out. When tannin is not present, carbon improves the test for residual phosphate by making the tricalcium phosphate sludge more filterable.

The equipment required for the phosphate test is as follows:

- One phosphate color comparator block of two standards—30 ppm and 60 ppm of phosphate as PO_4. (The Taylor high-phosphate slide comparator may be used instead.)
- Four combination comparator mixing tubes, each marked 5, 15, and 17.5 ml, with stoppers.
- One filter funnel, 65-mm diameter.
- One package of filter paper, 11 cm in diameter.
- One 20-ml bottle.
- One 0.5-ml dropper.
- One 1/4-tsp measuring spoon or spatula.
- Two plain test tubes, 22 mm by 175 mm (about 50 ml).
- Two rubber stoppers, No. 3 flask.
- One 250-ml glass-stoppered bottle or flask, labeled comparator molybdate reagent.

The reagents you need are as follows:

- One 32-oz comparator molybdate.
- One 2-oz concentrated stannous chloride.
- One 32-oz standard phosphate test solution (45 ppm of phosphate, PO_4).

One pound decolorizing carbon. (This is a special grade of decolorizing carbon tested to make sure it does not affect the phosphate concentration in the sample.)

For test purposes, the stannous chloride is supplied in concentrated form. The reagent must be diluted and should be prepared from the concentrated stannous chloride on the day it is to be used, because the diluted solution deteriorates too rapidly for supply by a central laboratory. If not fresh, diluted stannous chloride gives low test results. Concentrated stannous chloride also deteriorates and should not be used if more than 2 months old.

The procedure for making diluted stannous chloride is as follows:

1. Fill the 1/2-ml dropper up to the mark with the concentrated stannous chloride.
2. Transfer it to a clean 20-ml bottle.
3. Add distilled water up to the shoulder of the bottle, then stopper and mix by shaking.

CAUTION

Any diluted stannous chloride not used the day it is made should be discarded.

The following procedure is used to make the test for phosphate:

1. Without disturbing any settled sludge, transfer enough of the sample to the test tube to till it about half full.

2. Add 1/4 tsp of decolorizing carbon. Stopper the tube and shake vigorously for about 1 minute. The carbon absorbs the tannin so it can be filtered out.

3. Fold a filter paper and place it in the filter funnel. Do not wet down the filter paper with water. Filter the shaken sample, using a combination mixing tube as a receiver. The carbon absorbs tannin, and the tannin and sludge present are filtered out more rapidly. Avoid jiggling the funnel, as unfiltered boiler water may overflow the edge of the filter paper into the tube. You have to support the funnel.

4. After 5 ml of the sample has filtered through, as indicated by the level in the tube, discard it. Continue filtering to bring the level in the test tube again up to the 5-ml mark. The sample should come through clear and free, or nearly free, of any color from the tannin. If not nearly free of tannin color. repeat the test, using 1/2 tsp of carbon. adding it in two 1/4-tsp portions, shaking it for 1 minute after each addition.

5. Add the comparator molybdate reagent to bring the level up to the second mark (15 ml). Stopper and mix by inverting the tube several times.

6. Add fresh diluted stannous chloride up to the third mark (17.5 ml). Stopper and mix by inverting. If phosphate is present, the solution in the mixing tube turns blue.

7. Place the tube in the comparator block. Compare the color of the solution in the tube with the standard colors of the phosphate color block. Colors between the two standard colors may be estimated. Take the reading within 1 minute after adding the stannous chloride, because the color fades quickly.

8. Record the results as LOW, if below 30 ppm; HIGH, if above 60 ppm, or OK, if between 30 and 60 ppm.

Test for Tannin

The purpose of the TANNIN TEST is to determine the amount of tannin in the boiler water. Tannin holds sludge in suspension. In treating boiler water with tannin, control the dosage by the depth of brown formed in the boiler water by the tannin. To estimate the depth of the color, which is necessary in adjusting tannin dosages, compare a sample of the boiler water with a series of brown color standards of successively increased depths of color. A tannin color comparator, which is used for the comparison, has five glass color standards: No. 1, very light; No. 2, light: No. 3, medium; No. 4, dark; and No. 5, very dark.

The kit for the tannin test contains the following:

- One tannin color comparator
- Two square tubes, 13-mm viewing depth
- One plain test tube, 22 mm by 175 mm
- One filter funnel, 65 mm by 65 mm
- One package of filter paper, 11 cm in diameter

making this test, you first fill a plain test tube almost to the top with cool boiler water. Then place a square test tube in the slot of the comparator, and insert the filter funnel in it. Fold a filter paper and place it in the funnel without wetting it down. Filter water from the plain test tube into the square tube until the tube is neatly full. Remove the square tube from the comparator and hold it up to a good source of natural light. Note the appearance of the filtered boiler water. Is it free of suspended solids and sludge? If not, refilter the sample, using the same funnel and filter paper. Repeat, using a double filter paper if necessary, until the sample does come through free of suspended solids and sludge.

To complete the test, place the square tube of filtered sample in the middle slot of the comparator. Then compare the color of the sample with the five standards, viewing it against a good source of natural light. The color standard most closely matching the color of the filtered sample gives the tannin concentration of the boiler water. For a number of boiler water conditions, the tannin dosage is usually satisfactory if it maintains a medium (No. 3) tannin color. If the tannin color is too high, blow down; if too low, add tannin.

Test for Caustic Alkalinity (OH) without Tannin

The boiler water sample for this test is collected at a temperature of 70°F or below.

The equipment required is as follows:

- Two 8-in. droppers with bulbs
- Two 250-ml glass-stoppered bottles or flasks labeled causticity No. 1 and causticity No. 2
- Four marked test tubes, 22 mm by 185 mm
- Three plain test tubes, 22 mm by 175 mm
- Three rubber stoppers, No. 2
- One 14-in. test-tube brush
- One test-tube clamp
- Two 9-in. stirring rods
- One 1-oz indicator dropping bottle for phenolphthalein
- One test-tube rack
- The following reagents also are required:
- One 24-oz bottle or flask causticity reagent No. 1
- One 24-oz bottle or flask causticity reagent No. 2
- One 4-oz bottle phenolphthalein indicator

The following are the steps to follow in conducting a test for causticity when tannin is not used:

CAUTION

Avoid exposure of the sample to the air as much as possible to reduce absorption of the CO_2.

1. Without disturbing the settled sludge, fill a marked test tube exactly to the first mark (25 ml) with some of the original boiler water sample.

2. Shake causticity reagent No. 1 (barium chloride solution saturated with phenolphthalein) thoroughly and add enough to the graduated tube to bring the level exactly to the second, or long, mark (30 ml).

3. Stir the solution with the 9-inch stirring rod, which must be kept clean and reserved for the causticity test only. When the mixture remains colorless or does not turn pink, the causticity in the boiler water is zero and the test is finished. When the mixture turns pink, causticity is present. (If the pink color is not deep, intensify it by adding two drops of phenolphthalein indicator to the mixture in the tube.) Add causticity reagent No. 2 (standard one-thirtieth normal acid), using the 8-inch dropper, thatch must be kept clean and reserved for the causticity test only. Causticity reagent No. 2 is sucked from the reagent bottle into the dropper by its rubber bulb and added, drop by drop, to the test tube. After each addition, stir the mixture with a stirring rod. After sufficient reagent has been added, the pink color disappears; the change point is usually sharp. As soon as the pink color just fades out, stop adding the reagent.

4. The amount of causticity reagent No. 2 required to make the pink color disappear shows the concentration of hydroxide (OH) or causticity in the boiler water. The amount of reagent used is shown by the marks on the test tube above the long mark (30 ml). The distance between any two marks on the test tube equals 5 ml, and readings less than 5 ml can be estimated. For example, when only three fifths of the distance between the long mark and the next mark above were filled, then 3 ml was added. When the distance filled was past one mark plus three fifths of the distance to the next, then 5 + 3 = 8 ml was used. To obtain the actual ppm of hydroxide or causticity shown by the test, multiply the number of ml by 23. This constant number, 23, represents the amount of sodium hydroxide in the boiler water by volume. Thus, for 8 ml of causticity reagent No. 2, there are 8 x 23 = 184 ppm hydroxide or causticity in the water.

5. Record the results of the test in a boiler log or chemical log and adjust the range to meet requirements. When causticity is too high, blow down; if too low, add sodium hydroxide (caustic soda).

Test for Caustic Alkalinity (OH) with Tannin

For this test, start with a warm sample of about 160°F. It may be reheated by placing the sample-collecting container in a stream of hot boiler water drawn through the boiler water cooler connection. In a test for causticity when tannin is used, make sure you observe the same precautions as carefully as when tannin is not used.

CAUTION

Avoid exposure of the sample to the air as much as possible to reduce absorption of the CO_2.

The equipment and reagents required for this test are the same as those listed in the preceding section where tannin was not used.

The procedure for conducting a test for causticity with tannin is as follows:

1. Fill two test tubes to the first mark (25 ml) with some of the original boiler water sample, taking care not to disturb the settled sludge in the container. (Transfer as little sludge as possible from the sample-collecting container to the test tubes.)

2. Shake causticity reagent No. 1 thoroughly and add enough to each of the two marked tubes to bring the levels up to the second, or long, mark (30 ml). Stir both with the stirring rod, which must be kept clean and reserved for the causticity test only.

3. Stopper both tubes and let them stand until any sludge formed has settled to the bottom. The sludge carries down with it much of the tannin or other colored matter in the solution; settling takes a few minutes if the sample is warm.

4. Without disturbing the sludge at the bottom, pour enough solution from the tubes into the third marked tube to fill it to the second, or long, mark. Discard the mixture left in the first two. When the sample in the third tube is still warm, cool it by letting cold water run on the outside of the tube. It is sometimes possible to intensify the pink color by adding two drops of phenolphthalein from the indicator-dropping bottle to the sample in the tube. Stir the solution. When it is not pink, the causticity in the boiler water is zero.

5. When the sample is not pink, the test is finished. But if the mixture turns pink, proceed in the same manner as directed in Steps 3, 4, and 5 when no tannin is used.

Here is a brief explanation of an ALTERNATE PROCEDURE for making the test for causticity when tannin is used. In this procedure any glass container, such as a large test tube or graduated cylinder, marked for 50 to 60 ml can be used instead of the two standard marked test tubes used in Steps 1 and 2 above. With the large test tube or graduated cylinder, the warm (160°F) sample is added up to the 50-ml mark and causticity reagent No. 1 up to the 60-ml mark. Stir the mixture and stopper the tube, or graduate. After the sludge settles, pour off enough of the solution into one of the standard marked test tubes to fill it to the long mark (30 ml). When the sample is warm, cool it by letting cold water run on the outside of the tube. Adding two drops of phenolphthalein may intensify the pink color. When the solution is not pink, the causticity in the boiler water is zero. But if it turns pink, proceed in the same manner as in Steps 3, 4, and 5 when no tannin is used.

Test for Sodium Sulfite

The sample for this test should be cooled to 70°F, or below, and exposed to the air as little as possible, because oxygen in the air combines with sodium sulfite in the sample and causes low readings. Collect a separate sample, using the boiler water sample cooler, with the line reading to the bottom of the sampling bottle. Allow the boiler water to run until a few bottlefuls overflow to waste.

The equipment necessary to make the sodium sulfite test is as follows:

- Two marked test tubes
- Two plain test tubes
- One stopper for plain test tube
- One stirring rod
- One 8-in. dropper
- One 1/4-measuring tsp
- One 50-ml beaker
- One 150-ml beaker
- One 30-ml acid-dropping bottle, with dropper marked at 0.5 ml for hydrochloric acid 3N
- One 30-ml starch-dropping bottle, with dropper marked at 0.5 ml for starch indicator

The reagents required are as follows:

- One 2-oz bottle of potato, or arrowroot starch
- One 8-ml vial of thymol
- One 24-oz bottle of hydrochloric acid 3N
- One 1-pt amber bottle of standard potassium iodate-iodide reagent

The starch indicator for this test must be prepared locally. The procedure to adhere for good results is as follows:

1. Measure out a level one-fourth tsp of potato or arrowroot starch and transfer it to the 50-ml beaker.

2. Add a few milliliters of distilled water and stir the starch into a thick paste, using the end of the stirring rod.

3. Put 50 ml of distilled water into the 150-ml beaker. (It is convenient in this step to have the 150-ml beaker marked at the point where it holds 50 ml, or one of the marked test tubes can be used by filling it with distilled water to the fourth mark above the long mark.)

4. Bring the water in the 150-ml beaker to a boil by any convenient method.

5. Remove the source of heat and immediately pour the starch paste into the boiling water while stirring the solution.

6. Put a crystal of thymol into the starch solution and stir. After the solution has cooled, pour off any scum on the surface and transfer 30 ml to the indicator-dropping bottle.

7. The starch solution loses its sensitivity as an indicator after a time. Addition of the thymol preserves it for about 2 weeks. The starch should be dated when prepared.

In making the sodium sulfite test, proceed as follows:

1. Transfer 1 ml of hydrochloric acid 3N to a clean, marked test tube by measuring out 0.5-ml portions with the dropper of the acid-dropping bottle.

2. From the starch-dropping bottle, transfer 0.5 ml of starch to the marked test tube.

3. Without disturbing any settled sludge in the sample, pour enough of the sample into the marked test tube to bring the level up to the first mark (25-ml). Stir the mixture in the tube with the plunger end of the stirring rod.

4. To add the standard potassium iodate-iodide reagent to the mixture in the marked test tube, have the marked test tube supported and the stirring rod placed in the tube, so the reagent can be added with one hand while the mixture is stirred with the other. Fill the 8-inch dropper with standard potassium iodate-iodide reagent from the stock bottle by sucking it up with the rubber bulb. (The dropper must be kept clean and reserved for this test only.)

5. Add the reagent to the mixture in the marked test tube, one drop at a time, counting the number of drops and stirring after each is added until a permanent blue color, which is not removed by stirring, is obtained. The standard iodate-iodide reagent reacts with sodium sulfite in the mixture, and the formation of the permanent blue color from the action of excess reagent with the starch shows that the iodate-iodide reagent has consumed all the sodium sulfite in the mixture.

6. Each drop of iodate-iodide reagent used (except the last one) indicates 5 ppm of sodium sulfite in the boiler water sample. To figure the concentration of sodium sulfite in the boiler water, multiply the total number of drops of the standard iodate-iodide reagent used, less one, by 5. For example, when 5 drops were used, subtract 1 from 5 = 4, 5 x 4 = 20 ppm.

7. Record the results of the test as ppm.

Test for pH

The value of pH indicates the degree of acidity or alkalinity of a sample. A pH of 7.0 represents the neutral point; the lesser values denote acidity; the greater values denote alkalinity. The test is made as soon as possible after you take the sample. Avoid exposure to the air as much as possible to reduce absorption of CO_2.

The following equipment is used in making the pH test of boiler water:

- Two vials of indicator paper, hydrions pH 10 to 20
- Two vials of indicator paper, hydrions C pH 11 to 12
- One 50-ml beaker
- One 2-oz bottle

In conducting the test for pH of boiler water, remove a strip of pH 10 to 12 indicator paper from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds; then remove it. When the sample does not change the color of the paper or colors it yellow or light orange, the pH of the sample is too low and the test is finished. When the paper turns orange or red, the pH is either satisfactory or too high.

In that case, remove a strip of paper of pH 11 to 12 from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds; then remove it. When the sample does not change the color of the paper or colors it a light blue, the pH is satisfactory. When the paper turns deep blue, the pH is higher than necessary. Blow down or reduce the dosage of caustic soda (NaOH).

Test for pH of Treated Condensate

In making a test for pH of treated condensate, take the sample from a point in the return piping near which condensation takes place, such as after a trap, or preferably where the return-line corrosion is known to occur. The sample must represent water flowing in the return lines. Water taken from the return tank, especially of large installations, generally shows a higher pH. A sample should not be taken from a collecting tank if other water, such as makeup, is received in the tank.

The equipment required for this test is as follows:

- One 4-oz brown bottle of condensate pH indicator
- One 1-oz indicator bottle, with dropper marked at 0.5 ml
- One 100-ml beaker, marked at 50 ml
- One 9-in. stirring rod, glass

In making a test for pH of treated condensate, proceed as follows:

1. Pour a freshly drawn sample into the testing beaker until it is filled to the 50-ml mark. You do not have to cool the sample.

2. Transfer 0.5 ml of indicator solution to the 50-ml testing beaker, using the marked dropper. Stir the solution in the beaker. If the color of the solution changes to light pink. the sample is NEUTRAL, or slightly alkaline; therefore, the condensate pH is satisfactory and the test is over.

3. Record in a log that the pH range is between 7 and 7.5.

4. When the color change is green, the sample is in the acid range and the boiler water must be treated with Amines. Treat the boiler water with Amines gradually (in small amounts at a time), and retest after each treatment. Amines are the only chemicals used to treat boiler water that will vaporize and leave with the steam and thereby protect the return system.

WARNING

Permission to treat with Amines must be obtained from your supervisor. Amines are volatile, poisonous, and in the alkaline range.

6. When the color change is red or purple, the sample is in an excessive alkaline (pH) range. In that case, reduce the Amines treatment gradually (in small amounts at a single time), and retest after each treatment. Remember, the condensate pH normal acceptable range is between 7 and 7.5.

Test for Total Dissolved Solids

The solu-bridge method is a simple and rapid way to determine the total dissolved solids (TDS) content. Ionizable solids in water make the solution conduct electricity. The higher the concentration of ionizable salts, the greater the conductance of the sample. Pure water, free from ionizable solids, has low conductance and thus high resistance. The solu-bridge instrument measures the total ionic concentration of a water sample, the value of which is then converted to parts per million. The solu-bridge test equipment and reagent are furnished by the supplier in a kit.

CAUTION

The model of the solu-bridge given below is not suitable for measuring solids in condensed steam samples or an effluent of the demineralizing process. A low-conductivity meter is necessary. because of the extremely low solids content of condensed steam and demineralized water.

The equipment and reagent are as follows:

- One solu-bridge, Model RD-P4 or equivalent, for a 105 to 120-volt, 50- to 60-cycle ac outlet. (This model has a range of 500 to 7,000 micromhos/cm.)
- One polystyrene dip cell, Model CEL-S2.
- One thermometer, 0°F to 200°F.
- One 0.1-g dipper for gallic acid.
- One cylinder, marked at the 50-ml level.
- Gallic acid powder, 1 lb.
- Calibration test solution. I qt.
- The test is made as follows:

Without shaking, pour 50 ml of the sample into the cylinder. Add 2 dippers of gallic acid powder and mix thoroughly with a stirring rod.

2. Connect the dip-cell leads to the terminals of the solu-bridge and plug the line cord into a 110-volt ac outlet. Turn the switch ON. and allow the instrument to warm up for 1 minute.

3. Clean the cell by moving it up and down several times in distilled water. Measure the temperature of the sample to be tested; then set the point of the solu-bridge temperature dial to correspond to the thermometer reading.

4. Place the cell in the cylinder containing the 50-ml sample. Move the cell up and down several times under the surface to remove air bubbles inside the cell shield. Immerse the cell until the air vents on the cell shield are submerged.

5. Turn the pointer of the solu-bridge upper dial until the dark segment of the tube reaches its widest opening.

6. Calculate the result in ppm by multiplying the dial reading either by 0.9 or by a factor recommended by local instructions. For example, when the dial reading is 4,000 micromhos and the factor used is 0.9, then 4,000 x 0.9 = 3,600 ppm.

7. Record the results of the test in ppm.

Q22. Scale deposited on metal surfaces of' boilers consists largely of what scale-forming element?

Q23. What are the two broad types or methods of chemical treatment of' boiler water?

Q24. Results of a phosphate test would need to be between what lower and higher ppm to be at an acceptable level?

Q25. In a causticity test without tannin, when the mixture turns pink, what does this mean?

Q26. A sample of boiler water for a sodium sulfite test should be cooled to what temperature before conducting the test?

CLEANING BOILER FIRESIDES AND WATERSIDES

Lesson Objective: Describe met hods and procedures involved in fireside and waterside cleaning.

Boiler heat transfer surfaces must be kept clean to provide for safe and economical boiler operation. In this section we will describe the methods and procedures involved in fireside and waterside cleaning.

CLEANING BOILER FIRESIDES

Excessive fireside deposits of soot, scale, and slag cause the following conditions: reduced boiler efficiency, corrosion failure of tubes and parts, reduced heat transfer rates and boiler capacity, blocking of gas passages with high draft loss and excessive fan power consumption, and fire hazards.

Methods for cleaning boiler tiresides include wire brush and scraper cleaning, hot-water washing. wet-steam lancing, and sweating.

Wire Brush and Scraper Cleaning

When too much soot is deposited and the passages become plugged, hand lancing, scraping, and brushing are generally used. Special tools required for reaching between the lanes of tubes may be made from flat bars, sheet metal strips cut with a saw-toothed edge, rods, and similar equipment. Some boilers have different sizes of tubes, so you need various sizes of brushes and scrapers to clean the boiler tubes. The brushes or scrapers are fastened to a long handle, usually a piece of pipe, inserted and pushed through the tubes.

Hot-Water Washing

This method of cleaning is often used to clean superheaters, economizers, and other sections of the steam generator that are difficult or impossible to reach by brushing or scraping. The water may be applied with hand lances and/or boiler soot blowers. Dry out the boiler setting immediately after water washing to reduce damage to the refractory and other parts of the setting.

Safety is always paramount; therefore, always be cautious when washing boiler firesides. Some precautions you should observe are as follows:

- Wet the boiler refractory and insulation as little as possible. Install canvas shields or gutters where possible to reduce wetting of refractories.
- Protect electrical equipment from water damage.
- Provide all necessary instructions and protective equipment for workers.
- Provide a compressed air lance to loosen scale after water washing.
- Provide adequate equipment to heat and pump the hot water. The water should be heated and maintained at a temperature close to about 150°F, because water exceeding this temperature cannot be handled safely and efficiently. However, because cold water does not clean satisfactorily, you have to maintain the water temperature as close as 150 degrees as possible. A water pressure of 200 to 250 psig should be provided at the cleaning lances or soot blowers. The water jets must penetrate the tube banks and strike with enough force to break up the slag accumulations.
- Start the water washing at the top of the unit and work down.
- The unit must be dried out immediately after washing.

Wet-Steam Lancing

The wet-steam lancing method is similar to the hot-water method except that wet steam is used instead of hot water. The steam should be wet and at a pressure of 70 to 150 psig. The unit must be dried out immediately after lancing is completed.

Sweating

Fireside slag can be removed from the convection superheaters by forming a sweat on the outside of the tubes. Cold water is circulated through the tubes. and moisture from the air condenses on the tubes to produce sweat. The hard slag is changed into mud by the sweat, and the mud can be blown off by an air or a steam lance. A large tank filled with water and ice can be used as the cold-water source. Steam can be blown into the area around the tubes during the cold-water circulating period to provide adequate moisture in the air.

Cleaning Procedures

The procedures for cleaning boiler tiresides are as follows:

1. Remove the boiler from service and allow it to cool. Make sure the boiler is cool enough for a person to enter. Someone must be standing by whenever a person is in the boiler. DO NOT force-cool the boiler.

2. Disconnect the fuel line openings. Secure all valves, and chain. lock. and tag all fuel lines to the burner and install pipe caps.

3. Disconnect the electrical wiring. Secure and tag the electrical power to the boiler. Disconnect the burner conduit and wiring. Mark and tag all electrical wiring to ensure proper reinstallation.

4. Open the boiler access doors by loosening all nuts and dogs and swing the door open. Be careful not to damage the refractory door lining.

5. Remove the burner from the boiler openings. Follow the manufacturer's instructions for specified burners. Wrap this equipment with plastic, rags. or other suitable protective coverings. Remember. soot and loose carbon particles must be kept out of the moving parts of the burner because they can cause the burner to malfunction.

6. Provide all spaces with free-air circulation by opening doors and windows, or provide fresh air by mechanical means. An assistant should be stationed outside the opening and be ready at all times to lend a hand or to be of service in case of a mishap.

7. Cover the floor area around the tube ends with drop cloths to catch soot. Position a vacuum cleaner hose at the end of the tube being cleaned. Keep soot from contacting wet areas because soot and water form carbonic acid.

8. Remove tube baffles where possible and pass a hand lance or rotating power cleaner brush through each tube slowly and carefully so no damage occurs to personnel or equipment.

9. Inspect tube surfaces for satisfactory condition before continuing on to the nest tube. Use a drop cord or flashlight for viewing through the entire length of a tube. Wire brush all tube baffles either by hand or use of power tools.

10. Apply a light coat of mineral oil to all cleaned surfaces. To do this, fix an oil soaked rag to the end of a brush or rod long enough to extend through the tubes and thoroughly swab each surface, including baffles. Mineral oil is the only lubricant that prevents rusting and also burns off freely without leaving a carbon deposit.

11. Clean all flat surfaces by brushing with the hand or power tools. Make sure that powered equipment is grounded.

12. Use an industrial vacuum cleaner to remove loose soot.

CLEANING BOILER WATERSIDES

Any waterside deposit interferes with heat transfer and thus causes overheating of the boiler metal. Where waterside deposit exists, the metal tube cannot transfer the heat as rapidly as it receives it. What happens? The metal becomes overheated so that it becomes plastic and blows out, under boiler pressure, into a bubble or blister.

The term *waterside deposits* include sludge. oil, scale. corrosion deposits. and high-temperature oxide. Except for oil. these deposits are not usually soluble enough to be removed by washing or boiling out the boiler.

The term *waterside corrosion* is used to include both localized pitting and general corrosion. Most, if not all, is probably electrochemical. There are always some slight variations (both chemical and physical) in the surface of boiler metal. These variations in the metal surface cause slight differences in the electric potential between one area of a tube and another area. Some areas are ANODES (positive terminals).

Iron from the boiler tube tends to go into solution more rapidly in the anode areas than at other points on the boiler tube. This electrolytic action cannot be completely prevented in any boiler. However, it can be reduced by maintaining the boiler water at the proper alkalinity and by keeping the dissolved oxygen content of the boiler water as low as possible.

The watersides of naval boilers may be cleaned in two ways—mechanically, by thorough wire brushing of all drums, headers, and tubes; and chemically. by circulating chemical cleaning solutions through the boiler.

Mechanical Cleaning

Before mechanical cleaning of watersides is begun, the internal fittings must be removed from the steam drum. The fittings (particularly the steam separators and apron plates) must be marked or otherwise identified as to position in the steam drum to ensure their correct reinstallation. All internal fittings must be wire brushed and cleaned before they are reinstalled.

Cleaning the watersides of the generating tubes requires a special tube cleaner. There are several types available, but perhaps one of the most common is the pneumatic turbine-driven tube cleaner shown in figure 1-31. This type of cleaner consists of a flexible hose, an air-driven motor, a flexible brush holder, and an expanding wire bristle brush. The turbine-driven motor consists of a set of turbine blades made to revolve when compressed air is admitted through the hose. The turbine-driven motor, in turn, drives the wire brush. There are several sizes of brushes available (figs. 1-32 and 1-33). Figure 1-34 shows a brush refill for the type of brush shown in figure 1-32.

Before you start cleaning tubes, be sure that adequate ventilation and lighting have been arranged. Someone should also be stationed outside the drum to act as tender and to assist whomever is working in the drum. Keep a written checkoff list of all tools and equipment taken into the watersides and be sure that the same tools and equipment are removed.

With the air shut off, insert the tube cleaner in the tube until the brush is about even with the far end of the tube. Wrap friction tape, a rag, or some other marking

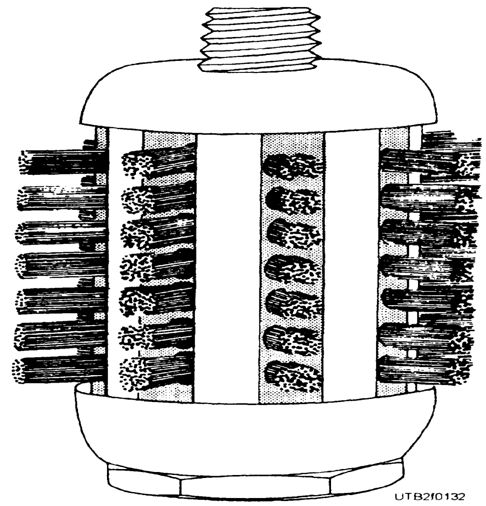

Figure 1-32.—Wire bristle brush for cleaning generating tubes.

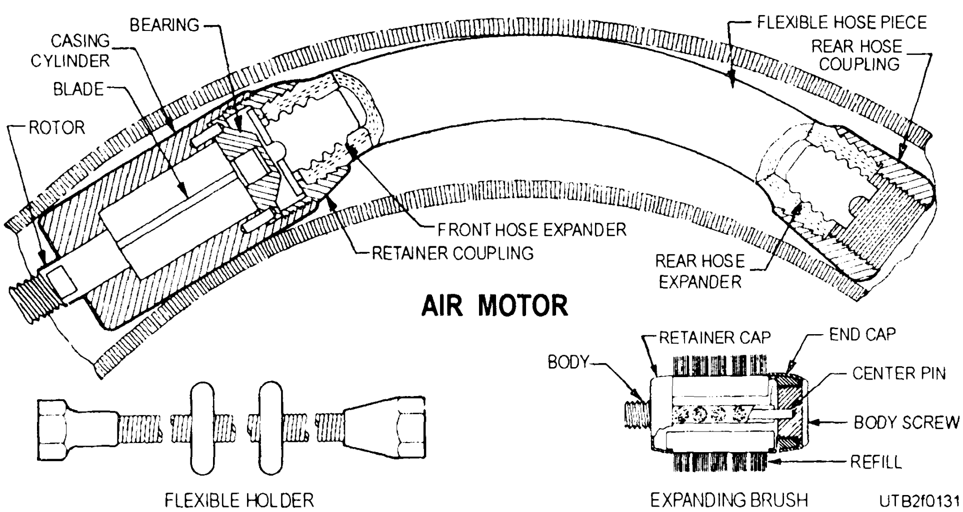

Figure 1-31.—Boiler tube cleaner (pneumatic turbine-driven type).

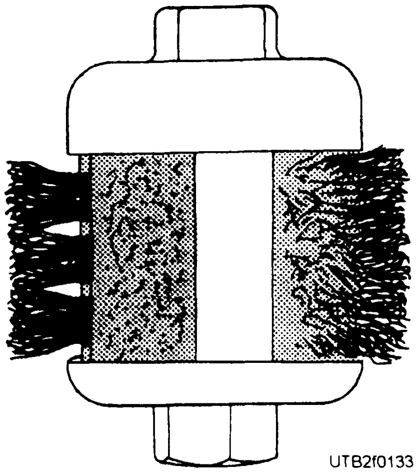

Figure 1-33.—Wire bristle brush for cleaning large tubes.

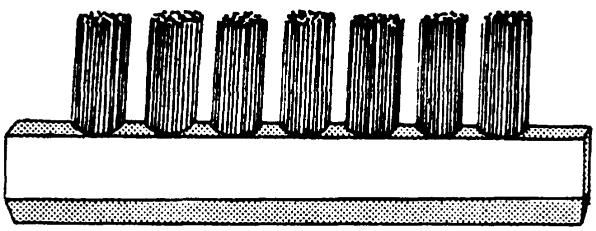

Figure 1-34.—Brush refill.

material around the hose to show how far the tube cleaner can be inserted without having the brush protrude beyond the far end of the tube. Then remove the cleaner from the tube. Remember that the tubes in each row are the same length; however, the tube lengths vary from row to row. Therefore, separate markings have to be made on the hose for each row of tubes.

After the hose has been marked, insert the brush in the tube and turn on the air to start the brush rotating. Pass the brush SLOWLY along the length of the tube until the identifying mark has been reached. Then slowly draw the brush back. withdrawing the cleaner from the tube. You do not have to shut off the air to the tube cleaner each time the cleaner is withdrawn from the tube. However, be sure to steady the brush assembly with your hand to keep the cleaner from whipping. Allowing the brush to whip at either end of the tube is the most common cause of broken tubes.

Establish a new mark for the next row and proceed with the cleaning. Make as many passes as necessary through each tube to ensure adequate cleaning. Be careful not to stop the tube cleaner in any one place in the tube, as the continued rotation of the brush in one place might damage the tube. Be careful, also, to see that the brush and the flexible shaft do not protrude from the other end of the tube, as this may result in a broken shaft.

The tube is most easily cleaned from the steam drum. However, some rows of tubes are not accessible from the steam drum and must be cleaned from the water drum or header. The lower ends of ALL tubes must be cleaned from the water drum or header. You may also find tubes bent so that brushes cannot be forced around the bend without breaking the tube cleaner. These tubes must be cleaned from both ends. Tube cleaners must be kept in good operating condition. The rotor and blades of the air motor should be kept clean and well lubricated. The hose connections should be kept tight and free from leaks. The flexible shafts should be inspected frequently and renewed when they show signs of wear or damage. When the brushes become too worn to work efficiently, a new set of brush refills should be inserted into the brush body. Store tube cleaners in a clean, dry container.

After all tubes, drums, and headers have been cleaned and after all tools and equipment have been removed from the watersides, blow through the tubes with air; then wash out the drums, tubes, and headers with fresh water. Ensure all dirt is removed from the handhold seats. Then examine the seats for scars, pits, or other defects that might cause leakage. All bottom blow, header blow, and test cock valves should be inspected and repaired under the manufacturer's instructions during each waterside cleaning.

After washing, thoroughly dry out the boiler watersides. Inspect the watersides to determine the condition of the metal to see if the cleaning was satisfactory. Also, inspect the boiler to be sure that all the parts are tight. Be sure that all openings between drums and gauge glasses, blow valves, and safety valves are clean and free of foreign matter. These openings are sometimes overlooked.

Chemical Cleaning

In most cases. mechanical cleaning is the preferred method for cleaning watersides. Chemical (acid) cleaning requires special authorization. since it requires elaborate and costly equipment and rather extensive SAFETY precautions. However, you may have to use the chemical method, so a limited discussion on it is given here.

Inhibited acid cleaning is used to remove mill scale from the watersides of new or recently serviced boilers. When compared with mechanical cleaning, acid cleaning of boilers has the following advantages:

- Less outage time is required.

- Less dismantling of the unit.
- Lower cost and labor.
- A more thorough job is accomplished because the acid reaches areas inaccessible to mechanical cleaners.
- Because the cleaning is more complete, it is possible to examine the unit thoroughly for defects, such as cracks and corrosion pitting.

ACIDS FOR CLEANING.—The following acids are used to clean boilers: hydrocholoric acid, phosphoric acid, sulfamic acid, citric acid, and sulfuric acid.

HYDROCHLORIC ACID is most frequently used for boiler cleaning because it has a relatively low cost and satisfactory inhibitors are available. Also, the chemical reactions of the hydrochloric acid with the boiler deposits usually result in soluble chlorides.

PHOSPHORIC ACID can remove mill scale from new boilers. With this acid, the boiler can be fired directly without producing noxious or corrosive fumes. Direct firing produces good circulation and distribution of the cleaning solution. Another advantage of phosphoric acid cleaning is that the metal surfaces resist corrosion after cleaning. When cleaned with phosphoric acid, you must protect metal surfaces from surface corrosion during draining and before neutralization.

SULFAMIC ACID is available in powder that must be placed in solution. The powdered acid is easier and safer to handle than liquid acids in carbons. It does not produce noxious fumes as it dissolves and it is less corrosive than hydrochloric acid, especially at higher concentrations and temperatures.

CITRIC ACID AND SULFURIC ACID are used for removing boiler waterside deposits. Sulfuric acid is economical and easily inhibited. However, a danger is that the sulfuric acid can form insoluble salts, such as calcium sulfate.

INHIBITORS.—Without inhibitors, acid solutions attack the boiler metal as readily as they attack the deposits. With the addition of suitable inhibitors, the reaction with the boiler metal is greatly reduced. Inhibitors used include arsenic compounds, barium salts, starch, quinolin, and pyridin. Commercial inhibitors are sold under trade names by various chemical concerns. Other inhibitors are manufactured by companies that furnish complete acid cleaning services.

SAFETY PRECAUTIONS—When acid cleaning a boiler installation, you must observe SAFETY precautions as follows:

- Before acid cleaning, replace all brass or bronze parts temporarily with steel or steel alloy parts.
- Provide adequate venting for safe release of acid vapors.
- Close all valves connecting the boiler with other piping or equipment.
- Provide competent chemical supervision for the cleaning process.
- Do not exceed the specified acid and inhibitor allowable temperature. The inhibiting effect decreases with the temperature rise and the probability of acid attack of the boiler metal increases.
- After acid cleaning, be sure to thoroughly flush out all of the tubes that are horizontal or slightly sloping. Obstructions in these tubes can cause poor circulation, overheating, and failure of tubes when the unit is placed in service.
- Use goggles, rubber gloves, and rubber aprons when handling acids.
- Slowly pour the acid into water when mixing the solutions.

CAUTION

NEVER POUR WATER INTO ACID.

- Do not chemically clean boilers with riveted joints.
- During acid cleaning, hydrogen gas can develop through the reaction of the acid on the boiler metal. Some of the generated gas becomes part of the atmosphere inside the boiler, and the remainder is absorbed by the boiler metal, then liberated gradually. Because hydrogen air mixtures are potentially explosive, be careful when opening a unit for inspection after acid cleaning. Until the atmosphere within the boiler pressure parts has been definitely cleared of explosive gases, do NOT use open flames. flashlights, lighting equipment. or anything that might produce a spark near the openings to the pressure parts. Do NOT enter the boiler. The unit can be cleared of explosive gases by thoroughly flushing the unit with warm water with a positive overflow from the highest vent openings. The water temperature should be as near

to 212° F as possible to accelerate the liberation of hydrogen absorbed in the metal. After opening the unit, place air blowers at the open drum manholes to circulate air through the unit. Use a reliable combustible gas indicator to test the boiler atmosphere for explosive mixtures.

ACID CLEANING PROCEDURES—Boiler units can be acid cleaned by either the "circulation" or "fill and soak" method. The circulation method (fig. 1-35) can be used to clean units with positive liquid flow paths, such as forced circulation boilers. The inhibited acid solution is circulated through the unit at the correct temperature until test analyses of samples from the return line indicate that the acid strength has reached a balance and no further reaction with the deposits is taking place. Because the strength of the acid solution can be determined frequently during the cleaning process, this method can be more accurately controlled and can use lower strength solutions than the fill-and-soak method.

The fill-and-soak method (fig. 1-36) is used for cleaning units with natural circulation. The boiler unit is filled with the inhibited acid solution at the correct temperature and allowed to soak for the estimated time. It is not possible to obtain accurate representative samples of the cleaning solution during the soaking period.

FLUSHING AND NEUTRALIZING—After acid cleaning, drain and then flush the unit with clean, warm water until the flushing water effluent is free of acid and soluble iron salts.

Next, a neutralizing solution is circulated through the unit until the effluent shows a definite alkaline reaction. The types of neutralizing solutions used are as follows: soda ash, trisodium phosphate. sodium tripolyphosphate, or other nontoxic chemicals. After circulation of the neutralizing solution, the water level can be dropped to the normal level and the boiler fired at 50 psig with open vents to permit the escape of liberated gases. Finally. the boiler is again drained and flushed with clean, warm water.

Boiling Out

New boilers. or boilers that have been fouled with grease or scale, should be boiled out with a solution of boiler compound. New boilers must be washed out thoroughly. The steps required for one method of boiling out are as follows:

1. Dissolve 5 pounds of caustic soda and 1 1/2 pounds of sodium nitrate or 10 pounds of trisodium phosphate for each 1,000 gallons of water the boiler holds at steaming level. Put the mixture into the boiler as a

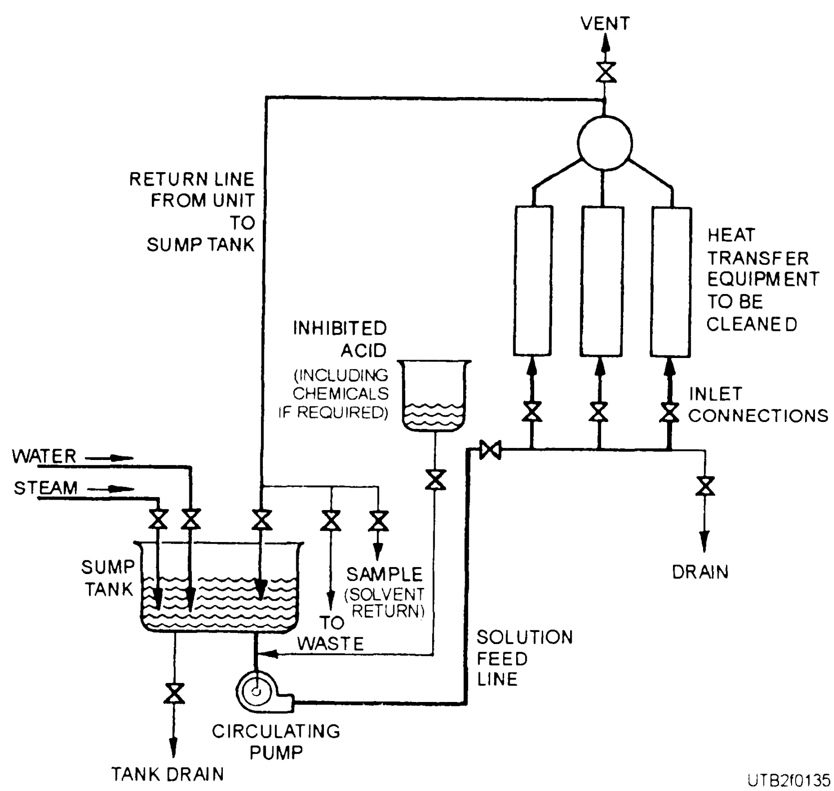

Figure 1-35.—Acid cleaning by circulation method.

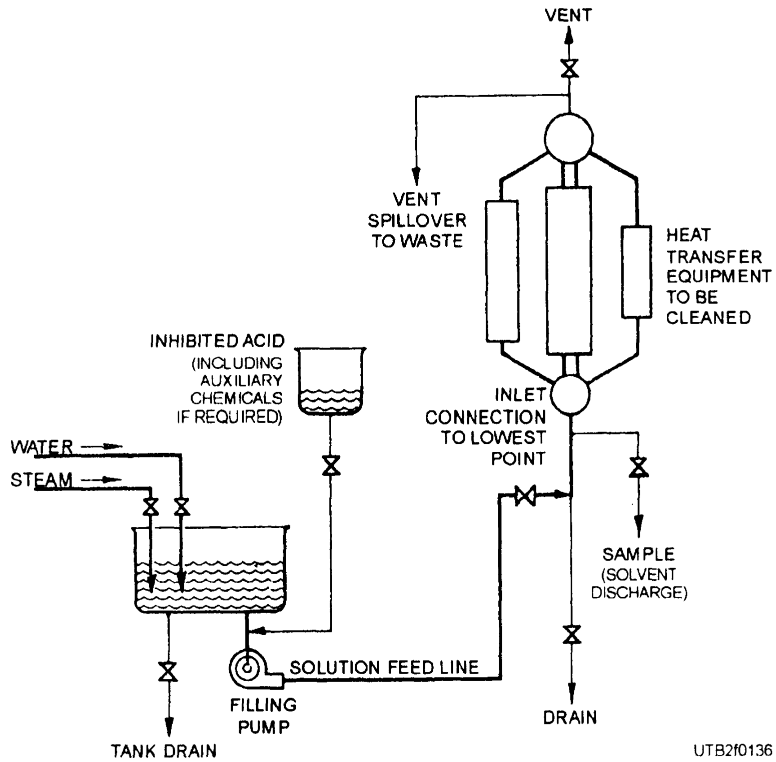

Figure 1-36.—Acid cleaning by fill-and-soak method.

solution. In multiple-drum boilers, divide the charge and put equal amounts in each of the lower drums.

2. Fill the boiler with hot feedwater to the level of the bottom of the steam drum. Turn the steam into the boiler through the usual boiling out connections, or bottom blow, and allow the boiler to fill gradually to the top of the gauge glass.

3. Steam pressure in the boiler should be kept between 5 and 10 pounds. The boiling out should continue for 48 hours. Immediately after boiling out, give a series of bottom blows to remove the bulk of the sludge. The boiler should be cooled, washed out immediately, and given the usual mechanical cleaning.

You may not always want to use the above method for boiling out. The steps for a second satisfactory method for boiling out are as follows:

1. Clean out all loose scale and any scale adhering to the boiler that can be removed manually.

2. Place about 15 pounds of caustic soda or soda ash and 10 pounds of metaphosphate for each 100-boiler horsepower (hp) of the boiler.

3. Seal the boiler openings but OPEN ALL VENTS. Fill the boiler about three-quarters full with water.

4. Start the burner and raise the temperature of the water in the boiler to about 200°F. Maintain this temperature for about 24 to 48 hours. Add makeup water as required during this period to fill the boiler to the base of the safety valve.

5. Analyze the boiler water during the boiling out period and add enough caustic soda and metaphosphate to maintain the following concentrations:

Causticity as ppm OH 300 to 500

Phosphate as ppm PO_3 100 to 150

6. Open the boiler at the end of the boiling-out period and clean out the sludge and loose scale. Pay particular attention to removing scale and sludge from water legs in fire-tube boilers.

7. Flush the boiler thoroughly.

8. If a lot of corrosion is exposed when the scale is removed, notify your superior so a boiler inspection can be made.

When the boiler is operated, any residual scale may cause faulty operation. The boiler should be taken out of service at frequent intervals to remove sludge formed from disintegrated scale. As soon as personnel can work in the boilers, wire brush the drums and ends of all tubes.

Then clean the interior of all tubes, using the approved style of boiler tube cleaning brushes.

You should operate all cleaners in the same way. After cleaning all the tubes, follow up by blowing them out thoroughly with a strong air jet. Then inspect to see if replacement of any of the tubes is necessary.

Q27. What are the four methods used to clean boiler firesides?

Q28. What pressure range should steam be for effective wet-steam lancing?

Q29. What conditions are considered waterside corrosion?

Q30. What acids are used for cleaning boiler watersides?

Q31. What are the two methods of acid cleaning?